APRIL 1960

SAE

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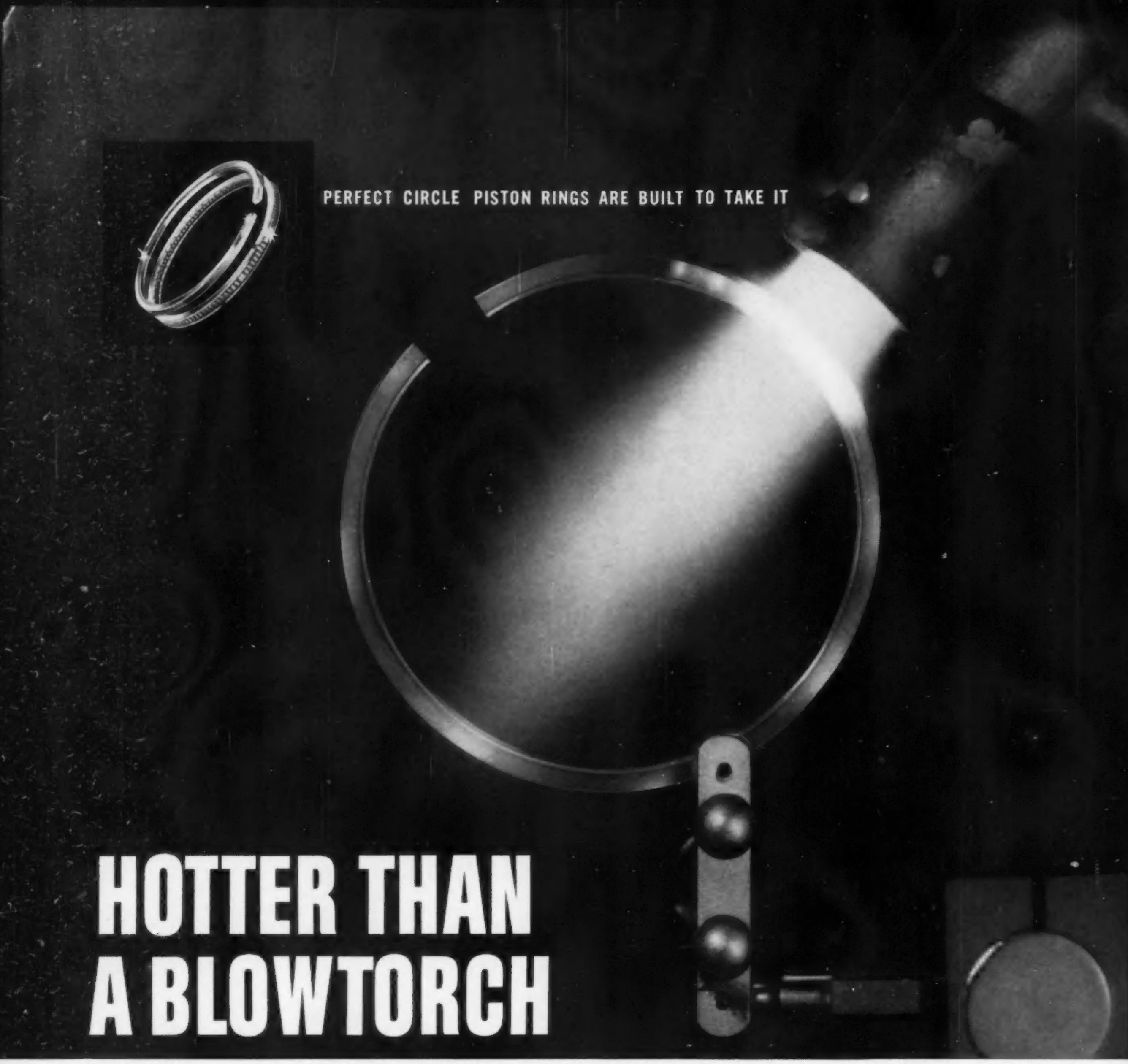
JOURNAL



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A complete index of all Journal technical articles, from January through December, will appear in the December issue. All Journal technical articles are indexed by Engineering Index, Inc. SAE Journal is available on microfilm from University Microfilms, Ann Arbor, Mich.

Briefs of SAE PAPERS

Presented here are brief digests of recently presented SAE papers. These papers are available in full in multilith form for one year after presentation. To order, circle the numbers in the "Readers Information Service" blank on page 6 corresponding to the numbers appearing after the titles of the digests of interest to you.

FUELS AND LUBRICANTS

Developing Transaxle Fluid, N. A. HUNSTAD, R. A. WILKINS, R. E. OSBORNE, E. D. DAVISON. Paper No. 117A. History of hypoid gear lubricant and efforts made by General Motors Research Laboratories in development of transaxle fluid for automatic-type unit; tabulation of lubricant requirements; plumbed car tests and other tests used for evaluating transaxle fluid; evaluation studies of 32 mineral-oil-base fluids, and 10 synthetic-base fluids; projected future studies. 53 refs.

Development of Transaxle Fluid for Chevrolet Corvair, J. W. CLARK, R. E. HARVIE, E. L. NASH. Paper No. 117B. Procedure followed in development of combination fluid to meet joint requirements of transaxle composed of automatic transmission and hypoid rear axle assembly; design features of Corvair Powerglide transmission; axle and transmission phases of transaxle fluid development; three stages of long range development program; laboratory bench and screening tests; proving ground proof-testing of vehicles; field and fleet testing.

Are Navy's Engine Oils Good Enough for Their Latest Diesels? J. R. BELT, L. G. SCHNEIDER. Paper No. 110A. Paper reviews U. S. Navy's participation relating to lubricant development programs; examples of lubrication problems of load carrying ability under boundary lubrication conditions, and exhaust port deposits; program undertaken at Naval Eng. Experiment Station to examine reported correlation between results obtained in Station's Kinetic Oiliness Test Machine (KOTM), and piston pin bushing lubricating ability of oils; summary of test results.

Laboratory Methods for Predicting Silver Bearing Performance of Lubricating Oils, L. O. BOWMAN, M. W. SAVAGE. Paper No. 110B. Silver bearings are employed in some internal combustion engines where bearing fatigue resistance is major requirement; bench test methods for evaluating silver lubrication characteristics of crankcase oils; it is shown that silver bearings operating principally in hydrodynamic lubrication region can be satisfactorily lubricated with oils that have low silver corrosion tendencies; KOTM silver friction procedure.

Jet Fuels, Past, Present and Near Future, W. S. MOUNT. Paper No. 114A. Summary of developments ranging from special kerosene, used as first jet fuel to military JP-4 fuel, developed to provide very large volume potential; tabulation of present military and commercial jet fuels.

Radiation From Flames in Gas Turbine Combustion, R. M. SCHIRMER, L. A. McREYNOLDS, J. A. DALEY. Paper No. 114B. Effect of monocyclic vs. polycyclic aromatic components, in JP-5 fuels having same ASTM Smoke Points, on total flame radiant energy studied by Phillips Petroleum Co., and U. S. Naval Air Material Center, Aero Engine Laboratory; tabulation of 12 test fuels; effect of variations in fuel composition on total flame radiant energy, flame luminosity, average and maximum combustor liner metal temperature and exhaust gas temperature of J57 combustor.

Relation of Fuel Properties to Combustion Cleanliness in Small Gas Turbine Engine, M. J. BOEGEL, J. F. WAGNER. Paper No. 114C. Study at Gulf Research Center to determine effects of fuels ranging from gasoline to diesel fuel on combustor deposition and exhaust smoking tendencies; results of light and heavy duty tests and continuous maximum power tests; de-

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Briefs of SAE PAPERS

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position tendencies of good and poor fuels could be predicted from several fuel properties and empirical fuel factors; naphthalenes and hydrogen-carbon ratio were among best correlation factors.

Startup Wear in Automobile Engines, M. L. KALINOWSKI and R. A. NEJDL. Paper No. S234. Factors affecting cold startup wear and what might be done to fuels and lubricants to reduce them are discussed. In fuels antirusts offer some control; in motor oils, detergents are the most helpful ingredients; but, taken together, antirust in the fuel and detergent in the motor oil do not reinforce each other. Thus, particularly valuable would be fuel additives and oil additives that work better together.

GROUND VEHICLES

Data Systems in AASHO Road Test, P. IRICK. Paper No. 116B. Experimental investigation on basis of three aspects: objectives involved, procedures for data acquisition, and methods for data analysis; essence of statistical method is to put all aspects on unified mathematical basis; example taken from AASHO Road Test illustrating concept; example involves 30 pavement sections two lanes wide; random process is used to determine their space order of occurrence in tangent.

Military Snow Removal Problems, E. C. KINKER, J. L. TERRY. Paper No. 115A. Requirements of equipment for snow and ice removal from airports and maintenance of communication lines (roads); example of prototype model snow removal carrier having 4-wheel drive, 4-wheel steer, and Hall Scott Model 6182-G-1 engine; four airport ice removers, developed by Corps of Engineers; Aerodrome Runway Sweeper, built by Sicard Industries, Inc.; 34,000-GVW army snow plow carrier capable of meeting highway axle loadings and width limitations.

Towing Tractors for Heavy Jet Aircraft, J. C. LAEGELER. Paper No. 115B. Chicago's O'Hare Field is used as example to illustrate how tractor design is influenced by layout and operating rules of airport; principal features and characteristics of 4-wheel drive, 4-wheel steer towing tractors, built by Frank G. Hough Co., Libertyville, Ill.; use of gasoline engine permits 37.5 Kva ground power unit to feed from same fuel tank, resulting in only one kind of fuel required for combined unit; other details.

Application of Automatic Control Techniques to Future Agricultural Machinery, W. E. KOCK, P. MAKER, C. B. SUNG. Paper No. 112B. Review of development of American agriculture; agricultural control systems and mechanism; principles of closed-loop systems; requirements in several areas and three specific examples of feasible developments; first example is one requiring simple on-off control; second utilizes numerical data processing system and control; third illustrates complex, multiple-function system with variety of control loops and associated sensors.

GMR Stirling Thermal Engine — Part of Stirling Engine Story — 1960 Chapter, G. FLYNN, Jr., W. H. PERCIVAL, F. E. HEFFNER. Paper No. 118A. External combustion engine which represents cooperative design of Philips Research Laboratories, Netherlands, and General Motors Research Laboratories, evolved during 20 yr program; inherent potentialities of ideal Stirling cycle in comparison to basic cycles of other engines are shown; physical engine and its method of operation; performance data from first two modern engines operated in United States.

Generalized Thermodynamic Analysis of Stirling Engines, T. FINKELSTEIN. Paper No. 118B. Case of limited heat transfer coefficient and variable exposed surface area for cylinder is treated in analysis; expressions for cyclic pressure and temperature variations of working fluid derived by using stepwise numerical integra-

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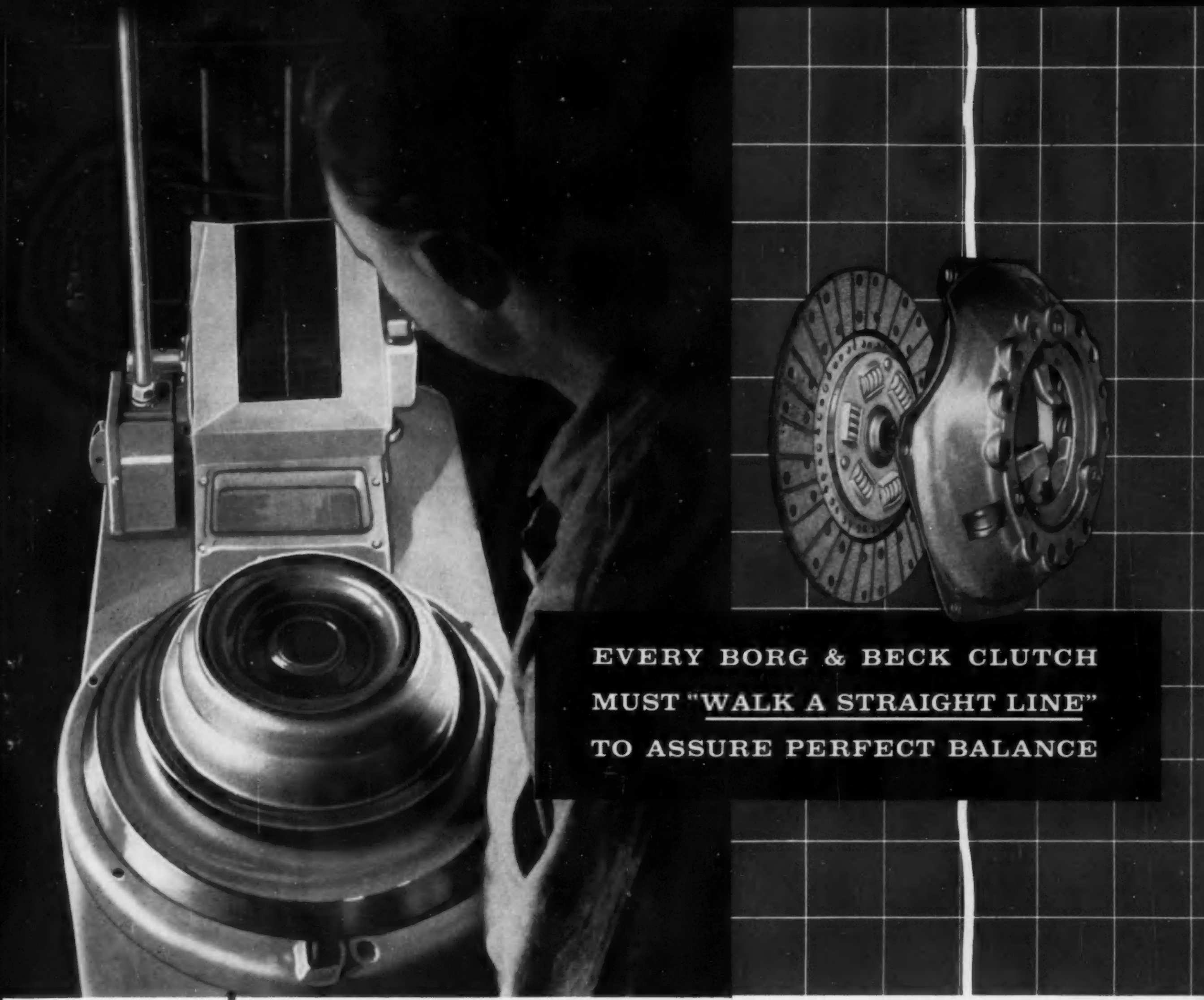
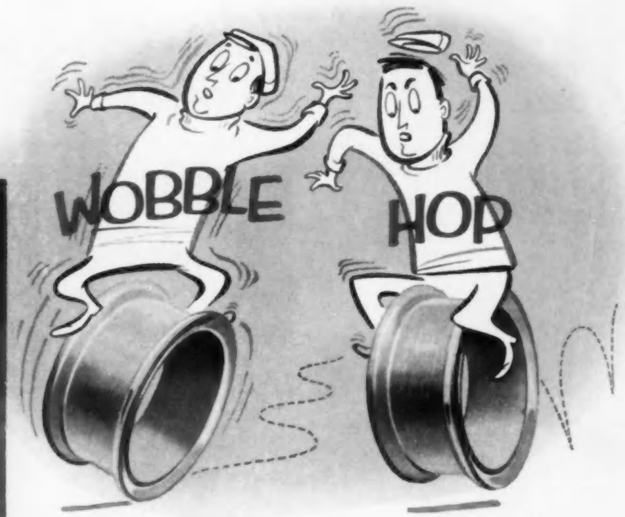

EVERY BORG & BECK CLUTCH
MUST "WALK A STRAIGHT LINE"
TO ASSURE PERFECT BALANCE

ride...and stop the HOP, too

than ever before——
yet developed

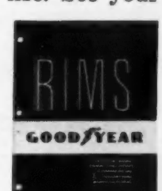


It's lateral and radial run-out—wobble and hop—that often makes long rides so fatiguing. Now, a new Goodyear rim development promises to make road travel smoother and more comfortable than ever before.

For today Goodyear rims are made to closer tolerances than ever. The result is a truer rim and truer running performance. Maintenance costs are reduced, too, with greater tire mileage an added benefit.

What's more, these new improved rims give you other tire advantages—such as better tread wear, less sidewall and bead failure, less tread cracking.

So more than ever, it makes good sense to buy and specify Goodyear Rims—job-fitted by Goodyear to insure longer rim life, longer tire life. See your local rim distributor, or write: Goodyear, Metal Products Division, Akron 16, Ohio.



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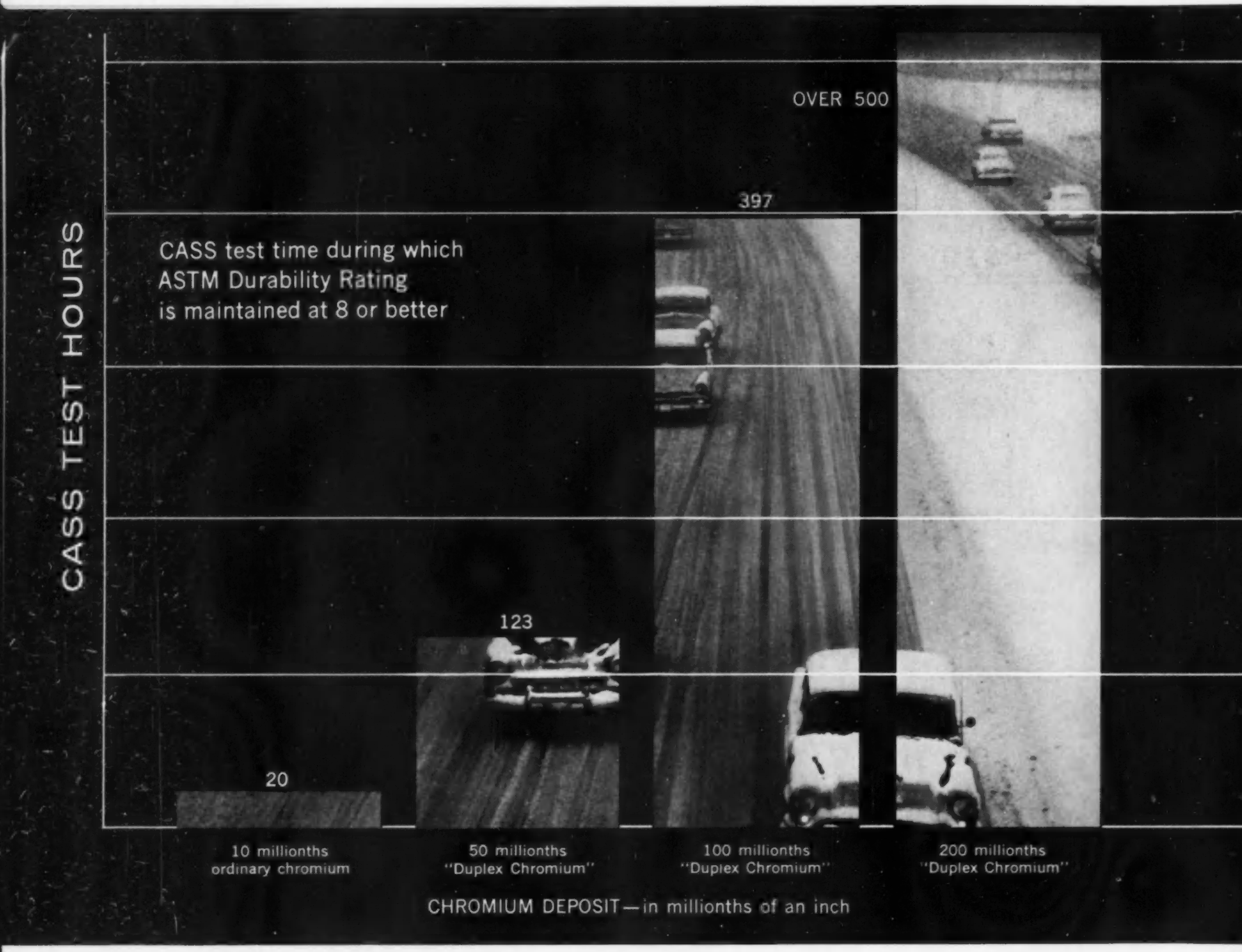

The thicker the "Duplex Chromium" ...the longer the plating lasts

You'll now do more to increase durability of plated parts with a little more chromium thickness properly applied than with any other change in plating specifications. Results with M&T "DUPLEX CHROMIUM" confirm this beyond all doubt. There's dramatic improvement with 50 millionths of an inch. With 100 millionths it's downright phenomenal . . . and with 200 millionths, you have the finish of the future.

The graph shows this clearly. These are results with zinc die castings plated with identical undercoats but with different chromium topcoats. See the difference M&T "DUPLEX CHROMIUM" makes in durability. Note that the thicker the chromium, the longer the service life expectancy. Corrodkote accelerated corrosion tests show the same pattern of protection and durability.

Experience shows that the only suitable way to plate thicker decorative chromium is with Unichrome SRHS® plating solutions. They make possible the correct *type* of deposit. They save production time. They simplify operations. And only with a combination of two of these baths can you produce M&T "DUPLEX CHROMIUM." Unichrome "Crack-Free" Chromium comes first, to block infiltration of corrosives to underlying metal. *Giving more uniform plate distribution,* this bath deposits ample thickness in recesses, with no graying on edges. A subsequent deposit of special Unichrome SRHS® Chromium then follows, to avoid localized corrosion at defects in the basis metal.

SRHS® baths and the "DUPLEX CHROMIUM" process can be adapted to most existing plating operations. Send for the M&T plating engineer to survey your plant requirements, or ask for literature.

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WHAT'S NEWS IN RUBBER

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There have been many elastomers developed since the first commercial ton of Butyl was used in 1943, but no other rubber, synthetic or natural, offers so many outstanding properties for so many applications.

Plant expansion plans announced recently will increase butyl production capacity some 50 percent by 1961 and, at today's rate of consumption, the two million-ton mark will be reached within the next six or seven years. Two new additions to the butyl product line, Chlorobutyl and Butyl Latex, will soon be available in commercial quantities.

VERSATILE ENJAY BUTYL'S OUTSTANDING PROPERTIES MAKE IT SUPERIOR TO OTHER RUBBERS FOR MANY APPLICATIONS. SOME ADVANTAGES:

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- **HAS WIDE RANGE OF DYNAMIC PROPERTIES** ... used in over 100 applications on the modern automobile
- **DISPLAYS OUTSTANDING CHEMICAL RESISTANCE** ... used for the storage and shipment of many chemical and commodity products
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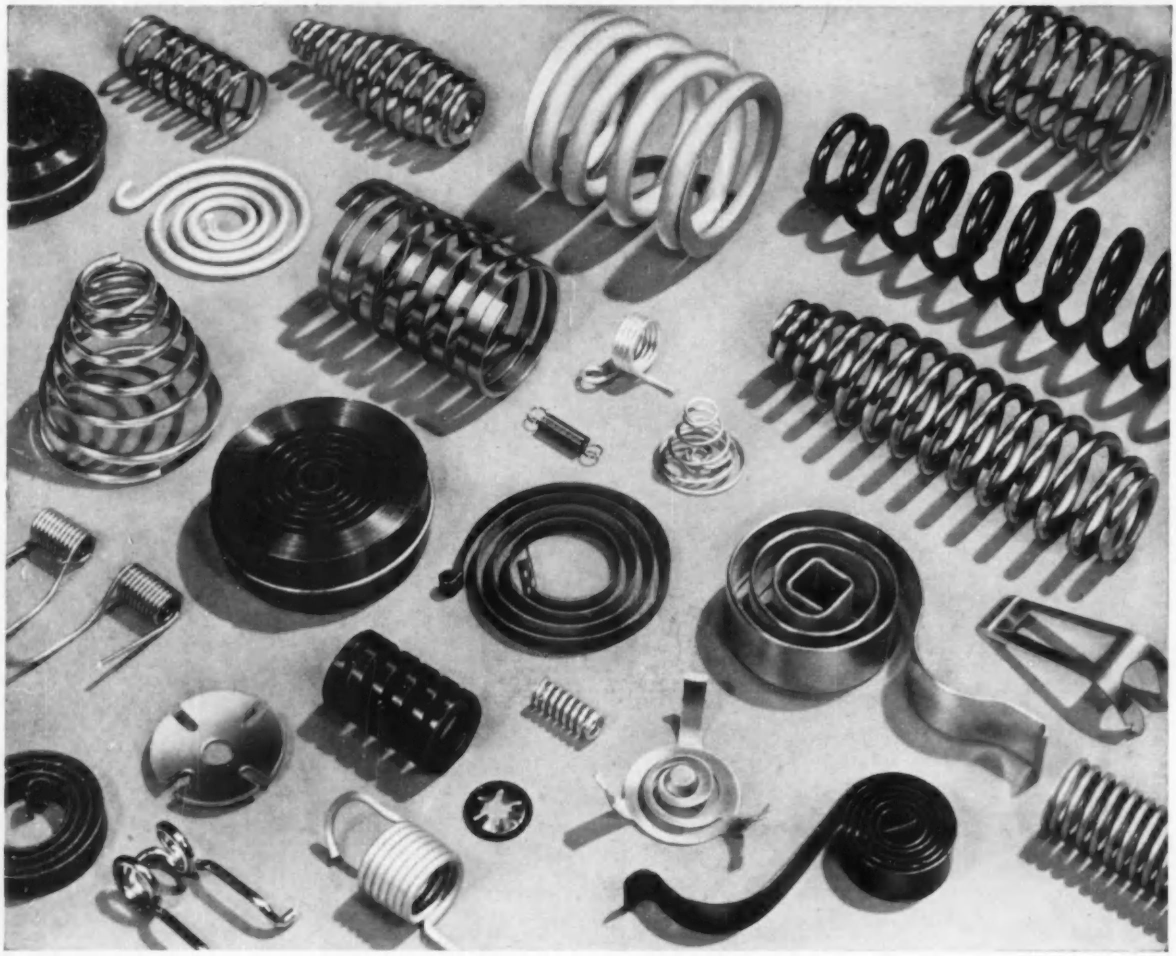

MORE MUSCLE IN A SMALLER PACKAGE . . . THE NEW

BLOOD BROTHERS "58WB"

UNIVERSAL JOINT

To meet new drive line requirements on its 1960 model trucks, a major truck manufacturer needed a special, lightweight but strong universal joint—a unit that would provide greater torque capacity without increasing swing diameter. Rockwell-Standard engineers were consulted, and in a cooperative effort the new "58WB" was developed. It is now being used on several models in the manufacturer's 1960 line.

The design of the new "58WB" is applicable to medium-weight trucks, off-highway equipment, small crawlers and front-end loaders of approximately 1½ yards capacity. It can be made up as a complete drive line, furnished as a component part for a manufacturer's own drive line, or utilized in close-coupled drives. The "58WB" offers these outstanding advantages:

★ **More capacity than any joint of comparable size.** The "58WB" provides 39,000 inch pounds torque capacity with a swing diameter of only six inches!

★ **Key-type yoke.** Requires only four bolts for installation on original equipment. Saves downtime for repairs.

For more details about the new "58WB" or for help in solving any problems involving universal joints or drive lines, write or call us today.

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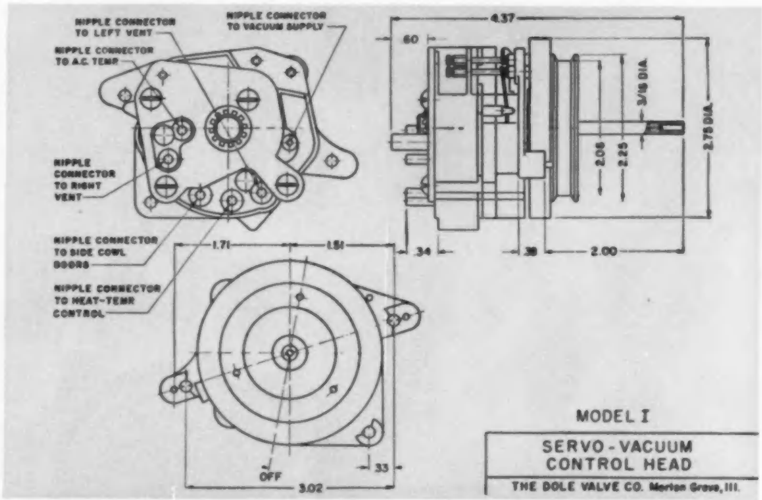
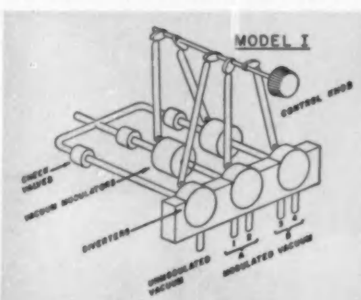
Universal Joint Division, Allegan, Michigan

New vacuum servo-system positions or actuates components at any distance from the control point

The matter of positioning or actuating components or operations at a distance from the control center is one that frequently poses problems for the automotive designer. Providing motion by means of Bowden wire has been the usual answer. Yet it has limitations. All too often the ideal location for a device cannot be used either because of its distance from the source of control or because it does not permit a sufficiently straight line of motion required for Bowden wire use. Consequently sound, practical design must be a compromise, at best.

In this new Vacuum Servo-System these and other major problems are eliminated. As the name implies, the motivating force is a vacuum and it is transmitted by means of flexible tubing. Consequently the devices or operations to which motion is to be supplied may be located in any position or at any distance from the control center. Therefore, such a system can be practical for the control of such things as temperature, air flow, liquid flow, position, pressure, rotation, velocity, ratio, or lock. In other words, here is a system which can be adapted to almost any problem involving motion at a distance.





THE VACUUM CONTROL HEAD—Depending upon its specific application, this system may make use of any or all of several units which include a Vacuum Control Head, Vacuum Switch, Vacuum Motor, Thermo-Sensing Unit, and Vacuum-Operated Water Valves.

The controlling unit is the Vacuum Control Head. This is an assembly of several vacuum control valves arranged in such a manner that they are opened, modulated and closed by the rotation of a single shaft. The programming of the entire system is determined by the configuration of the cam plate which actuates the individual valves. Thus, any desired sequence of control operation (for air duct shutters, thermostat settings, hydraulic selector valves, electrical switches, refrigerant valves, water valves, etc.) can be designed into the control head itself.

FULL SCALE MODULATION—Built-in adjustable vacuum regulators provide modulation of the pressure delivered to each vacuum motor resulting in smooth, calibrated positioning control of each device. An almost limitless variety of modulation effects can be provided.

THE VACUUM MOTOR—The actuating device of the system is a single stroke, spring-loaded vacuum motor. It consists of a special synthetic rubber diaphragm connected to a driving link held in its fully extended position by a calibrated spring. When vacuum is applied the diaphram moves back against the spring producing linear motion in proportion to the vacuum. In rest position the spring provides a strong force sufficient, for example, to insure positive closure of a vent door.

For applications in which it is desired to turn off one or more vacuum lines in response to a short linear control motion, a small single or multi-output valve is available. This is called a Vacuum Switch.

Also available is a Thermostatic Sensing Unit usually used with a correspondingly calibrated Vacuum Operated Water Valve to provide smooth and positive control of the output temperature of the heater.

WIDE VARIETY OF APPLICATIONS—The various units described here are subject to many combinations and each can be "tailored" to your own specifications. We suggest that you first consider the principles involved rather than the system as a whole. Then applying these principles to your problem may suggest ways in which the system may be of help to you. Bear in mind, the Dole Vacuum Servo-System is precision engineered, precision built by the Dole Valve Company, the principal supplier of engine thermostats and other controls to the automotive industry for more than 30 years.

THIS BOOK TELLS ALL—The new Dole Design Data Book No. 12-6001 describes and illustrates the system in complete detail. We shall be glad to send you a copy without obligation. Just write, on your firm letterhead, sign your name and position and mail to the—

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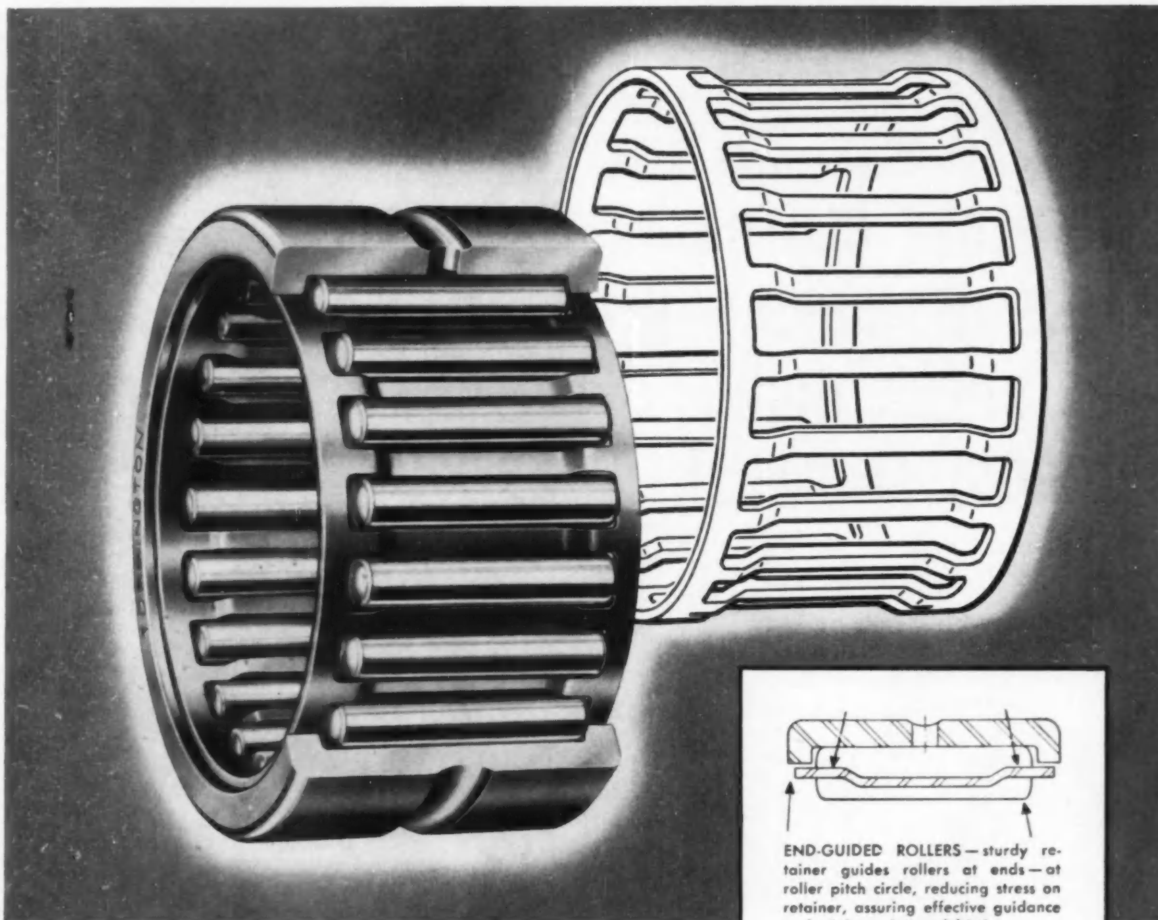
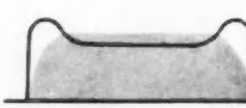
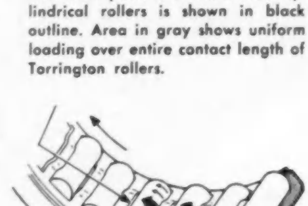


The New *Torrington Heavy Duty Roller Bearing*

END-GUIDED ROLLERS—sturdy retainer guides rollers at ends—at roller pitch circle, reducing stress on retainer, assuring effective guidance and minimum internal friction.



UNIFORM LOADING—Torrington controlled contour rollers eliminate stress concentration at roller ends. End-stress pattern of unrelieved cylindrical rollers is shown in black outline. Area in gray shows uniform loading over entire contact length of Torrington rollers.



AMPLE LUBRICANT STORAGE AREA is provided by the retainer design, which also allows unrestricted flow of lubricant within the bearing.

Key to Long Life... Roller Guidance Where It Counts!

This sturdy flange-riding retainer in Torrington Heavy Duty Roller Bearings insures the highest degree of roller guidance where it's most effective... at the roller ends along the pitch circle. You get outstanding service life through minimum internal friction, high roller stability and efficient lubrication.

Controlled contour rollers prevent high end-stress concentrations. Careful heat treatment of the channel-shaped outer race insures high shock resistance. The Heavy Duty Roller Bearing has proved successful under unusual conditions of deflection or misalignment. Torrington Heavy Duty Roller Bearings are giving longer life in such difficult applications as two-cycle engines, hydraulic pumps, oil-field equipment, sheaves and transmissions. For design and application assistance on the Heavy Duty Roller Bearing—and every basic type of anti-friction bearing—call your Torrington District Engineer.

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SAE
JOURNAL

For Sake of Argument

Life is Dynamic . . .

"LIFE IS dynamic and has to be treated as such," my philosopher friend opined the other day. "It is to be lived; not formulated," he went on, adding: "The end point is always unknown and wide open. Advance is made by gradually substituting a broader, clearer idea for each of the narrow ones we hold . . . which can happen, of course, only through the vitality of the new."

There's no doubt that our attempts to "formulate" our lives bring more frustrations than rewards. Just when we get a new formula going nicely, something from psychological outer space barges in to upset the balance. Only thing certain is that nothing material can be counted on to stay put. There is no factor of safety large enough to keep stable any fixed formula for living. The ability to encompass constant change, to *enjoy* new ideas for their own sake is the rare attribute which most steadily stimulates satisfactions in living.

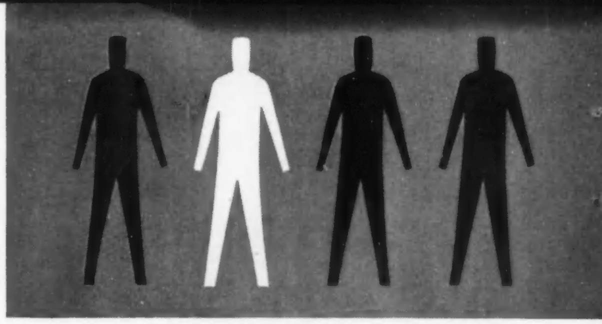
However, search for some formula-for-living is natural for most of us, perhaps even necessary. Even the mind which works like a constantly variable transmission has to be focused daily within some limits, when the man it's in has specific responsibilities for service or achievement. To finish a design, to get the production started . . . to put to practical use the research results from the science laboratory . . . all require a temporary locking of the mind to encompass decision for action . . . to get something done. And every decision involves some element of the arbitrary . . . of "formula."

We get into trouble only when we try to make tomorrow's situations fit into today's successful formula. But it's natural for us to try . . . because normal business pressures push us away from — not toward — "treating life as dynamic" . . . and "living it; not formulating it."

Norman G. Shidle

This is BENDIX PRODUCTS DIVISION...

"PROGRESSIVE SOURCE OF NEW AUTOMOTIVE DEVELOPMENTS"



One out of every four Bendix employees is technically trained. Bendix Aviation Corporation has one of the highest ratios of engineering and technical talent to manufacturing skill of any company. Another reason Bendix Products keeps new ideas coming at you.

More than 30 years ago, Bendix introduced four-wheel Duo-Servo brakes in this country. Since then, Bendix Products Division has continued to take an important part in automotive research and development, specializing in such components as brakes, power brakes and steering. And the Bendix success in these areas demonstrates our unusual ability to create products that have outstanding sales appeal as well as functional values.

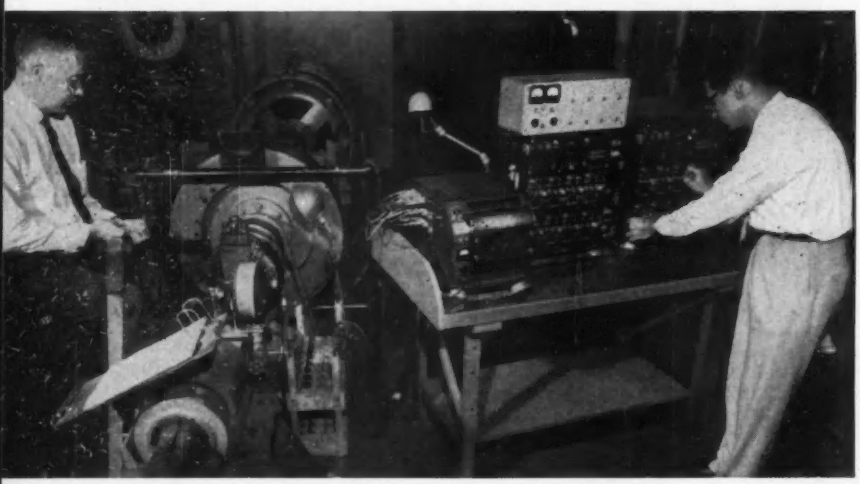
For example, power brakes pioneered by Bendix and bought by millions of today's car owners are the result of years of brake research and engineering study on every type of automotive vehicle.

Self adjusters in brakes, the latest Bendix development, supplement the appeal of safety with a powerful new economy feature. And power steering, the most wanted new feature on modern cars, provides still another striking illustration of Bendix Products Division's ability to develop improvements which, while eminently practical, also serve as powerful stimulants to car sales.

Just as today's automobiles reflect the foresight of Bendix engineers, tomorrow's motorist will benefit from improvements now being planned and perfected at Bendix.

The determination of Bendix Products Division to help make cars easier, safer and more economical to drive, and consequently more salable, is supported by the unique Bendix Research Laboratories and the 24 divisions of Bendix—as well as by this division's own well-staffed engineering team.

Vehicle manufacturers who share these worthwhile aims will find the nationwide resources of Bendix available and eager to assist them.



Latest type X-Y plotter permits greater accuracy and speed in checking the performance characteristics of power brake units.

Electronic instrumentation gives new dimensions to dynamometers, with increased utility plus more accurate and faster test data.

Specially designed hydraulic test equipment checks vital characteristics of components in the development of new power steering units.

Bendix PRODUCTS DIVISION South Bend, IND.

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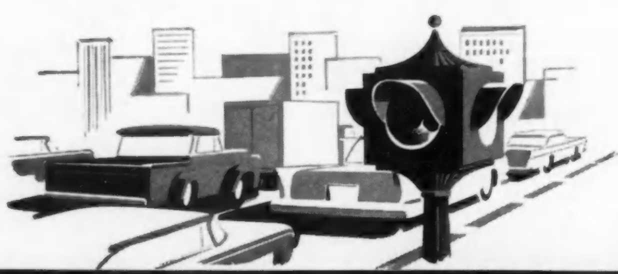

chips

from SAE meetings, members, and committees

IRRADIATION OF POLYSTYRENE-IMPREGNATED WOOD, according to a recent Russian report, gave a product with substantially greater strength and water and decay resistance than the unradiated product.

DURING WORLD WAR II there were hundreds of suggestions to the effect that troops should be equipped with microphones and amplifiers for the purpose of sharpening up their hearing so that they might be able to detect surprise attacks at night. These people were always surprised to hear that there was no known combination of microphone and amplifier which was capable of detecting a sound as faint as a man with normal hearing can hear with his unaided ear. The ear seldom has a chance to exert its maximum sensitivity. There are usually sounds in the background which are greatly in excess of the ear's threshold value, but in a proper soundproof enclosure the ear is able to distinguish a sound whose power is as little as 5×10^{-15} watts, under which circumstances the amplitude of the eardrum's vibration is about the same as the diameter of a hydrogen molecule.

PROPER ORIENTATION OF A WEAPON TO ITS TARGET is determined by direct external vision and by visual reference to a sight or scope. Therefore, the logical design origin for an aircraft is an eye position. The human body can be positioned about the eye; the cockpit can be arranged with reference to the body; and the rest of the aircraft design follows.

GEOBOTANISTS ARE HELPING IN THE DISCOVERY OF URANIUM and other important metals. They do this by studying the relationships between certain types of vegetation and their chemical environments. For instance, they discovered that the common western plant known as locoweed takes up large amounts of selenium when it is present in the soil — and selenium is found near uranium.

FIVE TIMES THE COST OF EQUIPMENT over a five-year period — that's the cost of maintenance for electronic equipment, a recent study shows. Designing equipment for a 50% increase in mean time between failures could result in a 20% decrease in total maintenance cost.

EASTERN TEACHES UNITED TO FLY UNDER THE WATCHFUL EYE OF THE FAA — After a recent meeting of Committee A-4, Aircraft Instruments, Chairman Fred Bonney of United Airlines was given a demstration of the finer techniques of flying by Gus Halwardson of Eastern Airlines while committee member O. E. Patton of the Federal Aviation Administration observed from the back seat of the Cessna 172. Bonney has a student pilot license with about 7½ hr flying time logged. Halwardson, foreman of Eastern's Instrument Overhaul Shop in Miami, started flying in Sweden in 1928.

Miami Fliers (left to right) O. E. Patton, Fred Bonney, and Gus Halwardson.

NEW PLASTICS

▸Recent progress portends new construction and

Based on paper by

Dr. Herman Mark

Polytechnic Institute of Brooklyn

SYNTHESIS and modifications of polymers are improving their performance and will give engineers an opportunity to employ new designs hitherto unimagined. This, rather than the added poundage per car sure to result, is the real value in polymer progress.

Significant progress is being made with polymeric materials in three directions:

1. The length and chemical character of the backbone chain.
2. The chemical nature of substituents along the length of these chains, their frequency, and the regularity of their distribution.
3. The pattern according to which the linear macromolecules are tied into a three-dimensional network.

Potential automotive applications now appearing on the horizons for plastics because of these polymer advances include: plastic gasoline tanks, plastic windows and windshields, plastic inner door surfaces, plastic roofs, all-plastic seats, and high-temperature-resistant-plastic wire coatings.

Backbone chain developments

The backbone chains of the linear macromolecules are formed, in general, by chemical bonds between carbon and carbon, carbon and nitrogen, or carbon and oxygen. In polyethylene, polyvinylchloride, and natural rubber, the strength of the backbone is provided by through-going or continuous carbon-carbon bonds building up chains of polymerization of many hundreds to several thousands.

In the case of polyacetals, polyesters, and polyamides there also exist carbon-oxygen and carbon-nitrogen bonds in the backbone. Examples are Delrin, Terylene, and 66 Nylon. These types of bonds pro-

Dr. Herman Mark

DISCOVERER of hundreds of polymers including polystyrenes, polyvinyls, polyacrylics, and synthetic rubbers, **Dr. Herman Mark** is also responsible for deriving the mathematical equations which today form the basis of polymer synthesis. As a consultant to du Pont chemists, Mark helped develop Dacron and Orlon.

In this article, Mark interprets the results of current polymer research in terms of its significance to automotive engineers.

Mark's industrial career began with I. G. Farben, the huge German drug and dye firm. He has directed research for a subsidiary of the Canadian International Co. Upon arrival in the U. S., Mark became a consultant to du Pont and Professor of Organic Chemistry at the Polytechnic Institute of Brooklyn. At Poly, Mark founded the Polymer Research Institute.

Known as Professor Polymer of Polytech, Mark is the holder of six honorary degrees, author of eight textbooks and more than 500 scientific articles, the editor of two scientific journals, and a consultant to many corporations.

for CARS...

mechanisms for the automotive field.

vide for perfectly satisfactory strength and resilience but will not permit preparation of materials which will support temperatures of 400–500 C over prolonged periods, or temperatures above 500 C for even a short time. It was backbone chains of silicon and oxygen that permitted these higher temperature domains to be penetrated, but the thermal and mechanical properties of the materials were not completely satisfactory.

Recently it has become possible to synthesize backbone chains of many types, some of which contain silicon and oxygen together with a metallic element such as Al, Ti, or Sn which leads to macromolecules where the free valences of the multivalent Al, Si, Sn, and Ti atoms are saturated with organic residues such as methyl, ethyl, or phenyl.

Spines of aluminum and oxygen have been synthesized which carry phenylated siloxen side chains, a combination which leads to materials of excellent heat stability and reasonable solubility in hot organic solvents. Other backbones are made by a combination of inorganic elements — Mg, Al, Si, Ti, and Sn — with oxygen and organic compounds.

The selection of proper combinations creates a multitude of new polymers which have excellent stability against mechanical deformation and the action of elevated temperatures. They will fulfill many of the requirements essential for wire coatings, gaskets, insulators, lacquers, finishes, and certain elastomers used in cars. They are still in developmental stage but will soon be valued aids to the automotive engineer.

Main chain substituents

Substituents, or side chains, which are attached to the backbone by chemical bonds, determine such important properties of the system as solubility, compatability, adhesion, hardness, and luster. Hydrocarbon substituents produce hydrophobic and oleophilic character with such favorable effects as water repellency, high dielectric strength, and low electric power losses, but with inadequate adhesion, high heat distortion, and sensitiveness to swelling in gasoline and oil. Strongly polar substituents impart hydrophylicity and oleophobility with excellent resistance to action of gasoline and oil, good adhesion, and high melting characteristics, but with pronounced sensitivity to swelling in water and deterioration from the action of oxygen and light. Between these two groups are the polar but hydrophobic substituents which allow creation of a series of interesting materials.

Polytetrafluoroethylene (Teflon), for example, has excellent electrical properties and remarkable stability against elevated temperatures, but its adhesive qualities are poor and the smoothness and simplicity of the backbone chain leads to pronounced cold flow. Modification of this molecule by incorporation of certain side groups, aided by copolymerization, has led to materials having much less flow under permanent loading.

Superior adhesive characteristics can be given a polymer by distributing along the length of its spine in adequate geometric distribution such groups as OH, CONHR, CN, and COOR. Their presence improves the binding capacity of the polymer with pigments and films and its compatibility with plasticizers. Thus the progressing art of introducing substituents leads to an almost incalculable number of combinations, each representing a compromise of desirable and valuable properties.

Three-dimensional networks

Polymeric materials can be strengthened by incorporating the individual linear macromolecules in a three-dimensional network. This is done by crosslinking which establishes strong chemical bonds between the chain molecules at predetermined sites in a predetermined concentration.

The activation of the crosslinking sites can be effected either by the presence of corresponding reactive groups (OH, NH_2, COOH) at the polymer chains, or by the addition of a crosslinking agent which reacts with two sites and establishes a chemical linkage between two polymer chains. Recently a large number of new agents of the peroxide, disulfide,

NEW PLASTICS for CARS . . .

. . . continued

diacrylamide, diisocyanate, and diepoxide type have been synthesized and can be used to control the degree of crosslinking and carry it out under widely varying experimental conditions.

The progress in the art of crosslinking represents an important addition to the advances made in other directions. All the new materials and methods together assure a continuous flow of improved and less costly materials into the hands of the automotive engineer to aid him in producing more efficient and less expensive cars.

Major breakthroughs on the horizon

The next major breakthrough for plastics in the automotive industry might very well be the all-plastic gasoline tank. It could be made from fire-resistant fiberglas-reinforced polyesters. It would provide an equivalent volume at 1/4–1/5 the weight of the present steel tank. No major fabrication problems would be presented. Adhesives could be used for sealing all joints. Pipe connections between the tank and the engine could also be made of plastics.

Another potential application for plastics in the automobile would be plastic windows and windshields. Some plastics are said to provide optical properties which now are as good as glass. Of course, plastics would have a weight advantage over glass. No ice would form on plastic windows and windshields because plastics are hydrophobic and present very little surface attraction to water in any form. Glass, on the other hand, is hydrophilic and the oxygen molecules in the glass do set up some attraction to the oxygen molecules in water tending to hold it onto the glass.

Although plastic windshields would require a surface-hardening treatment to prevent marring, they would still not be as brittle as glass. From a safety standpoint then, plastics have a great advantage. When plastics crack and break away into pieces, they break away with flat edges which are dull and cannot cut.

Engines, transmissions, and fuel systems offer many interesting and intriguing problems for the application of polymers. Here the main requirements are reversible and supple deformability over a wide temperature range, resistance against plastic flow, heat distortion, chemical degradation, and solvent swelling. Phenolics, polyamides, and fluoropolymers are now in use, in such capacities as fuel line tubings, gears, membranes, and gaskets. Better and less expensive materials will become available and the prospect is that there will be an increased use of polymers in the domain of the powerplant of a car in the near future.

Polymer compositions which perform as a finish or coating for a car must satisfy many demands, such as strong adhesion to the substrata; distinct capacity to hold pigments, reinforcing fillers, and plasticizers; pronounced resistance to softening under the influence of heat, light, acids, bases, salt solutions, and against the swelling in organic solvents. At the same time these compositions must have a high scratch resistance and surface gloss but should not chip off under impact or develop microcracks as a result of high frequency bending or stretching. The transition from the cellulose nitrate compositions to polyester based coatings and, more recently, to crosslinked acrylic type finishes represents a remarkable progress in the art, but the availability of new materials and new processing techniques strongly stimulates additional progress in the not too-distant future.

The plastics engineer will ask why larger parts of the doors and seats could not be made of polymers and it appears that recent progress in the vacuum forming of sheets and laminated foams and grids will stimulate the incorporation of more polymers in the body construction. All-plastic door-inner panels and moldings, plastic roofs, and all-plastic seats are just some of the possibilities here. Recently, in the automotive field, plastics have replaced metals in "kick" panelings.

In many applications metals and plastics working together may provide an optimum solution. A machined-steel gear meshed with a urethane-elastomer gear operates quietly, eliminates lubrication problems, and permits broader tolerances in design. In addition, such an arrangement will outwear all-metal or all-elastomer mated parts.

Vinyl-to-metal laminates are now being used for auto trim parts. Vinyl-coated steel sheets which are available today have the strength and rigidity of steel in addition to the color, texture, and abrasion resistance of vinyl plastic. Teflon without additives has been successfully held in bearings supporting 100,000 psi without displacement. Steel-backed spherical bearings have a cross-hatched mesh which prevents flow of the Teflon and keys the surface to the base material. In service Teflon takes on a high gloss and has a coefficient of friction of 0.004–0.005. Aluminum and brass can also be used as base materials. The bearing is impervious to water and many acids.

The electrical system of an automobile contains at present some 40 pieces where all kinds of insulating plastics or rubbers are used; the specific requirements include good mechanical properties over a wide temperature range, superior dielectric properties, firm adhesion to metals, insensitivity against moisture and hydrocarbon type liquids, and superior endurance under vibrational stress and compression at high and low speeds.

High-temperature-resistant wire coatings good for temperatures up to 250 C are a definite possibility here. Such a development would permit servomechanisms to run at higher current ratings. This, in turn, would allow smaller servos to meet present-day current requirements and result in a weight reduction.

To Order Paper No. 119A . . .
. . . on which this article is based, turn to page 6.

Abridgment of an
SAE Texas Section paper

Researches in

· *Electronic miniaturization*

· *Magnetohydrodynamics*

can have impact on our success in Space Flight

Based on paper by **George H. Stoner** Boeing Airplane Co.

INNOVATIONS that will affect the utility of space machines may come from advances in fields already recognized as necessary to space flight, such as electronic miniaturization. They can also come from fields not directly related by the laboratory experimenters in the field to any military application of space flight. An example of this latter might be magnetohydrodynamics.

Electronic miniaturization

Further advances in the art of miniaturizing electronic equipment are necessary for space flight. Recent progress and forecast gains are shown in Fig. 1. Component densities of 300,000 per cu ft are now realized, resulting in an increase greater than 10/1 over previous techniques. Research now being carried on in microcircuitry and molelectronic techniques will further improve component space utilization when applied. Over 1,000,000 components per cu ft may be realized, or an increase in component density of 5/1 over current values. To go beyond that we must try to devise computer elements as tiny and efficient powerwise as the synaptic connections arranged in the human brain.

The evolution of computing capability is of utmost importance in the field of applied cybernetics, as shown in Fig. 2. The start of computational automation, begun by Babbage in 1833, was stalled until 1937 when the automatic sequence calculator was built at Harvard University. This calculator fulfilled about one-fifth of the performance of Babbage's planned machine. With the application of electronic techniques, progress accelerated until today we have the IBM 704, the 7090, and many other manufacturers' products.

The possibilities growing out of a combination of

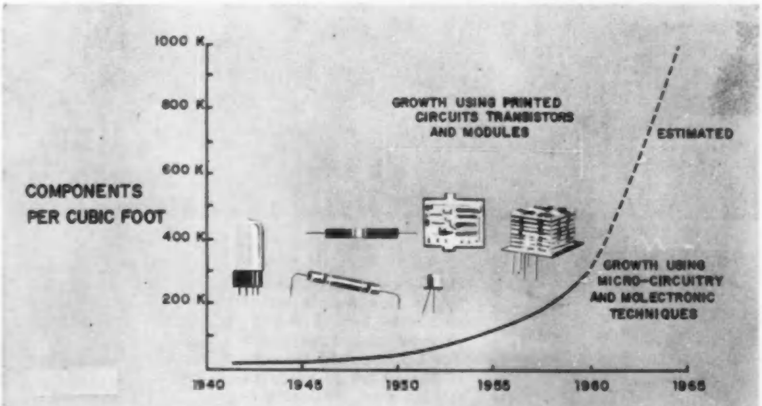

Fig. 1 — Progress in electronic miniaturization heralds the time when component densities of 1,000,000 per cu ft may be realized.

Our success in *Space Flight*

. . . continued

computational technology and microminiaturization techniques are immense. The 704 computer now occupies about 4000 sq ft of floor space. Through the use of cryogenic and molelectronic technology it will be possible in a very few years to put equivalent computing capability into a volume of a few cubic feet. A manmade package the size of the human brain can then commence to compete with man. Of course, the logic processes will all have to be programmed and stored. This seems a tremendous task, but the mechanization techniques are now with us.

Magnetohydrodynamics

Experiments are now being conducted in the control of plasma and ions to various ends. Work is being done on the general magnetohydrodynamic problem to produce more efficient propulsion, as shown in Fig. 3. Here a very-high-temperature plasma gas is being contained by a magnetic field, which prevents direct contact with the wall, the plasma being constrained to a flow pattern similar to that for a conventional rocket as it exhausts from the plasma chamber at enormous speed.

Laboratory workers are measuring the heat transfer rates to the chamber walls and the radiation losses from the plasma generated by an arc-jet in an effort to learn about magnetohydrodynamic interactions. An electrical discharge is used to generate the 250,000 K plasma (Fig. 4). Other workers are tackling the problems resulting from the high-temperature plasma surrounding a space vehicle on re-entering the earth's atmosphere at hypersonic speed.

The Argus experiment works with plasma to determine some of the fundamental properties of the space environment. Fig. 5 shows a nuclear explosion injecting electrons into the earth's magnetic field. The magnetic lines of force trap the electrons, constraining them in a sheath spreading around the earth, where they become a potential hazard to manned space flight. We are only beginning to explore the features of these man-induced radiations and of the even less certain solar-induced effects in the space surrounding our planet.

The most tremendous plasma experiments are being carried out in the control of nuclear fusion reactions. The progress made in this field is shown in Fig. 6. We are already working with plasmas at temperatures of millions of degrees in an effort to harness this source of energy.

All of these plasma experimenters may discover a greater utility to a knowledge of magnetohydrodynamics than any of the specific applications which guide their work today, especially when they combine the theoretical possibilities with continuously sustained flight through the high vacuum of space. Concentrated, controllable whirlpools of energy represented by plasma concentrations may have uses for communications or for weapon purposes in space flight, which are not yet being worked on directly. It may be necessary to have a space flight platform as a laboratory from which to conduct experiments of a massive nature, perhaps on the antiparticle phenomena that are now observed on a very small scale in the earth's laboratories.

To Order Paper No. S224 . . .
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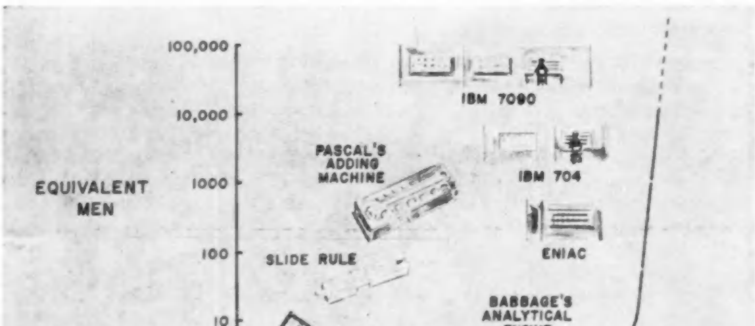


Fig. 2 — Cryogenic and molelectronic technology will soon make possible packaging within the volume of a few cubic feet the computing capability of a machine now requiring 4000 sq ft of floor space.

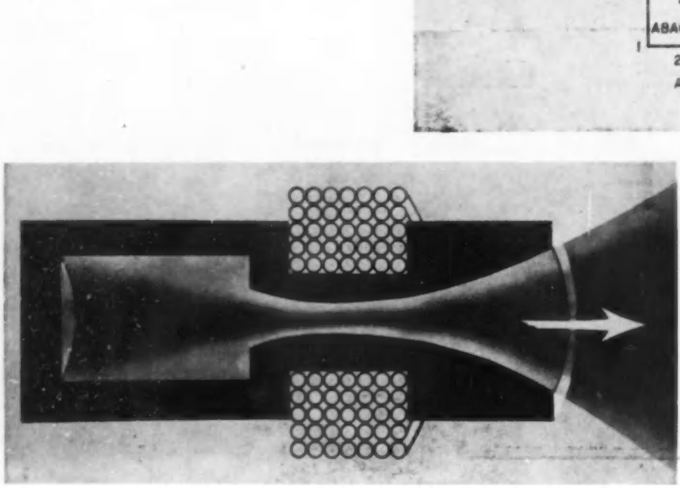


Fig. 3 — Magnetic channeling of flow from a rocket nozzle to keep high-temperature plasma gas from direct contact with the walls is one phase of research seeking more efficient propulsion.

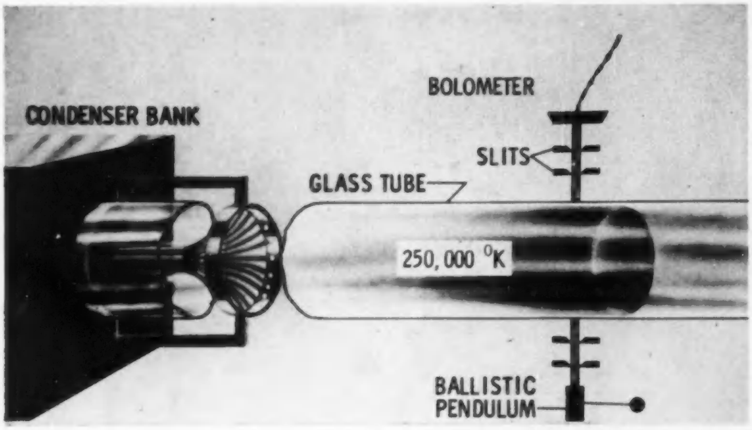
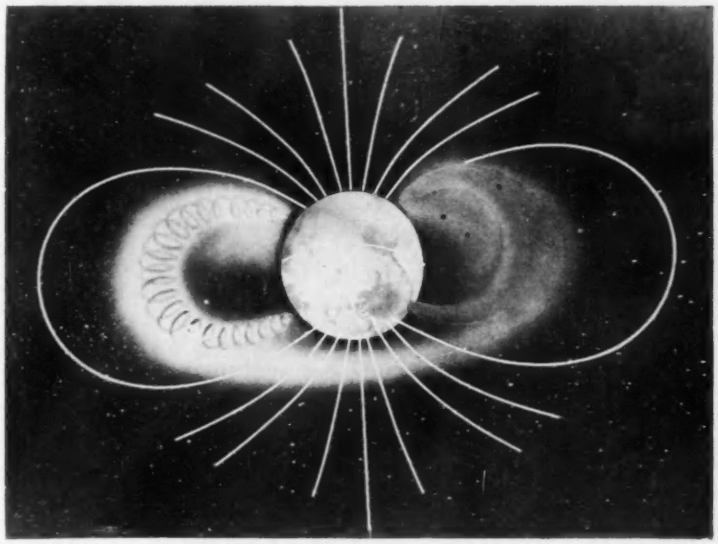


Fig. 4 — Researchers are measuring heat transfer rates to the Chamber walls and the radiation losses from the plasma generated by an arc-jet in an effort to throw light on magnetohydrodynamic interactions.

Fig. 5 — Electrons injected into the earth's magnetic field by nuclear explosion are trapped by the magnetic lines of force to form a sheath hazardous to manned space flight.



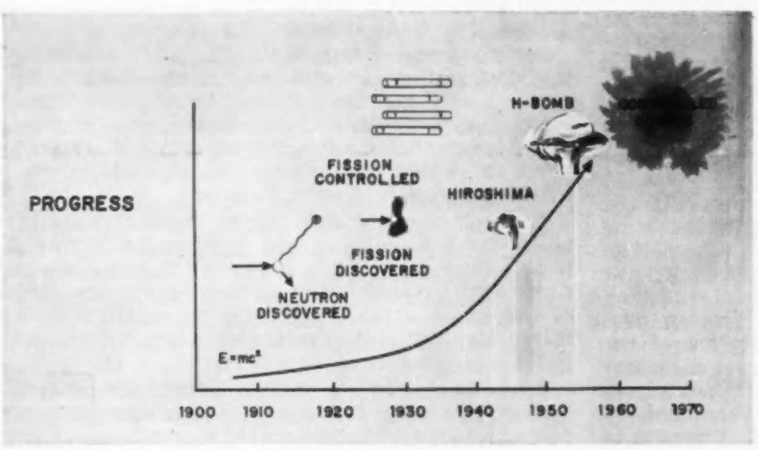
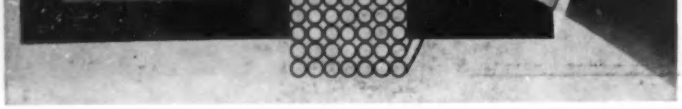


Fig. 6 — Spectacular development of nuclear energy beginning with Einstein's postulation of the equivalence of mass and energy, then step by step to the anticipated control of nuclear fusion reactions.



Now—

A Do-It-Yourself Computer

Based on paper by

J. T. Olsztyn, B. Hargreaves,
T. J. Theodoroff, and E. L. Jacks
GMC Research Laboratories

DYANA is a computing system for the IBM 704 computer. It permits engineers with little or no background in the use of digital computers, numerical analysis, or programming techniques to solve quickly and efficiently large classes of vibrational and equivalent dynamic problems. Two separate components of the system play a role in the solution of such problems: a programming language, and a set of computer instructions called the Dyana compiler.

The engineer uses the programming language to communicate his problem in a form acceptable to the computer. This form, called the Dyana program, consists of a description of the vibrating system being investigated, the mathematical expressions required to completely define the system, and a set of statements specifying the answers that are desired. Thus, a Dyana program is a declaration of a problem statement. It tells the computer what the problem is, but it doesn't prescribe how the problem is to be solved.

It is the role of the Dyana compiler to provide the solution to the problem. This it does by directing the computer to prepare a rigorous mathematical model of the problem, to set up the necessary numerical procedures for solving that model, and then to organize these procedures into a Fortran program. (A Fortran program is a collection of expressions or statements which instruct a computer to solve a problem. Many of these expressions have an algebraic-like appearance.) The subsequent execution of this Fortran program in the presence of appropriate data provides the desired answers.

Role of the Dyana language

Consider the simple vibrating system and associated Dyana program shown in Fig. 1. The vibrating system consists of a mass (rectangular box) which is attached to ground through a spring and a damper. The mass is also connected through a lever (with a fixed fulcrum) to another damper. This damper is connected to a spring which in turn is connected to ground. A force (the heavy arrow), applied to the mass, excites the system.

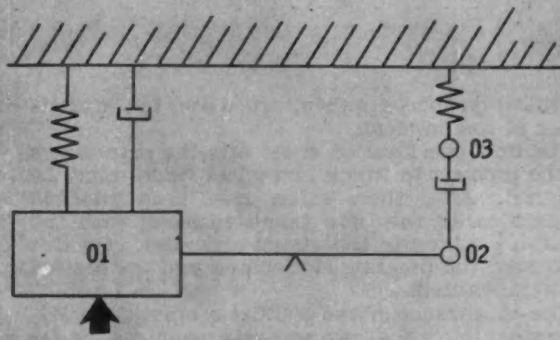
Note that all points in the system at which two or more elements are connected have been labeled with a two-digit number (other than *00*, which always represents a fixed ground point), for example, *01*, *02*, and *03*. These numbers distinguish and identify each degree of freedom of the system. And, this numerical labeling technique forms the basis for writing the Dyana program.

Let the problem depicted in Fig. 1 be the following: Determine, as a function of time and in the vertical direction, the acceleration of point *01*, the velocity of point *02*, and the displacement of point *03*. Assume that the force which excites the system has a value that at any instant of time (t) is given by the expression: $f_1 = 650.2 \sin (\pi t)$.

The collection of statements (Dyana program) below the schematic of Fig. 1 represents a formal Dyana expression of the problem. The statements describe the system being studied, specify the value of the exciting force, prescribe the answers to be solved for, and state the mode in which the computer is to produce those answers.

The meaning of the individual statements is as follows: X System Description means that the symbols appearing in subsequent statements up to the

for Engineers

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DYANA PROGRAM

X    SYSTEM DESCRIPTION
         E00K01, E00C01, E00M01, E01N02,
         E02C03, E03K00, EF01
X    FORCE, EF01
         EF01 = 650.2*SINF (3.1415*TIME)
X    PRINT-PLOT ANSWERS
         X03, DX02, DDX01, VS. TIME
```

Fig. 1 — Dyana program as applied to simple vibrating system.

next X statement describe the schematic. Thus *E00K01* means: The element (*E*) which is a spring (*K*), is connected between point *01* and ground (*00*). *E00M01* means the mass (*M*) element located at point *01*. The *N* of *E01N02* denotes a lever. The symbol therefore refers to the lever between points *01* and *02*. *E02C03* and *E03K00* refer respectively to the damper between points *02* and *03* and the spring between point *03* and ground.

X Force, *EF01* means that subsequent statements will define the value of the force *EF01* in terms of Fortran expressions. The expression for the force reads: The Force *EF01* is equal to 650.2 times (*) the sine (*SINF*) of the argument π times the Time (the independent variable of the problem).

The final two statements specify the answers the computer must solve for, as well as the form in which it has to make them available. The last statement can be interpreted to read: Print and plot on a single graph the curves: the acceleration (*DDX*) of point *01*, the velocity (*DX*) of point *02*, the displacement (*X*) of point *03* versus (vs.) time.

The seven statements just as they appear in Fig. 1 are punched into IBM cards and submitted to the computer. The sequence of events that then occur are explained with the aid of Fig. 2.

Role of the Dyana compiler

The first block in Fig. 2 represents the engineer's original problem statement. The next block shows the Dyana program as input to the computer. At the time that the Dyana statements are sent to the computer, the computer is loaded up with the set of instructions that constitute the Dyana compiler. The compiler then directs the computer to scan and analyze the incoming statements. After completing the analysis, the computer is next directed to set up the equations of motion. For the problem being considered here, these equations would have the form:

$$(E00M01)\frac{d^2x_1}{dt^2} + (E00K01)\,x_1 + (E00C01)\frac{dx_1}{dt} + F = EF01$$

$$E02C03\left(\frac{dx_2}{dt} - \frac{dx_3}{dt}\right) - \left(\frac{1}{E01N02}\right)F = 0$$

$$E02C03\left(\frac{dx_3}{dt} - \frac{dx_2}{dt}\right) + (E00K03)\,x_3 = 0$$

$$X_1 - \left(\frac{1}{E01N02}\right)X_2 = 0$$

F represents the reaction force exerted on points *01 and 02 due to small* deflections of the lever. When used in these equations, the symbol *E01N02* takes on the meaning: the lever ratio r_2/r_1; where r_1 is the distance from the fulcrum to point *01*, and r_2 is the distance from the fulcrum to point *02*.

After the equations have been set up, the compiler directs the computer to solve them. The solution at this point amounts to establishing a set of analytical and numerical procedures which, when applied to the equations, guarantee that the quantities

$$\frac{d^2x_1}{dt^2},\ \frac{dx_1}{dt},\ x_1\ \ \frac{dx_2}{dt},\ x_2,\ \frac{dx_3}{dt},\ x_3, \text{ and } F$$

can be determined for any value of the independent variable *t*. Next, the equations of motion, the procedures for solving them, and directions for printing and plotting specified answers are coded by the computer into a Fortran program. The last activities performed by the first computer of Fig. 2 is to punch out the entire Fortran program on IBM cards and to print out a set of specifications for preparing data cards. Both the Fortran program and the data

specification sheet are then turned over to the originator of the problem.

The data specification sheet lists the parameters of the problem to which numerical values must be assigned. After these values have been punched on data cards, they are submitted along with the Fortran program to the second computer. On this computer, the program is executed and the desired answers realized.

The appearance of two distinct computers in Fig. 2 does not imply that two separate machines are required by the Dyana system. The computers are in reality one and the same. They appear separately to point out the two phases involved in the solution of problems in the Dyana system. In the first phase, the computer accepts a problem statement written in the Dyana language and produces as output a set of instructions. In the second phase, that same computer executes these instructions and produces as its output the desired answers.

Problem applications

Although Dyana was designed primarily for the study of spring-mass-damper systems, it is capable of handling many other dynamics problems. As a rule, the Dyana system can be used to some extent in the study of most dynamics problems whose mathematical models are known to be adequately represented by systems of ordinary differential equations. Of this class of problems, many are directly analogous to spring-mass-damper systems. That is, the equations of motion of such systems are in form and structure identical with the equations of motion for spring-mass-damper systems. Only the units and meanings of the variables appearing in the equations are different. These types of problems are the easiest to set up in Dyana, for they require only the enumeration of the elements or components of the system and absolutely no derivation of the governing equations of motion. Electrical systems consisting of capacitor-resistor-inductor components are of this type, as are torsional spring-mass-damper systems. Direct analogies to spring-mass-damper systems can also be found in some aspects of thermal, hydrodynamic, and acoustical systems, to name a few.

Many dynamics problems do not exactly fit into the system description language of Dyana. In such cases, a simple transformation of the variables and components of the system usually can be made to fit them into the Dyana language. When this is done, the remainder of the analysis, the set up of the numerical procedure, and the complete programming of the problem are automatically handled by Dyana.

Two kinds of solutions

Two kinds of solutions are available in the Dyana system. One of these is generated by the Dyana compiler whenever information is requested which depends upon the behavior of the system as it varies continuously in time. This time-varying solution yields the instantaneous displacements, velocities, and accelerations of the system at discrete values of the independent variable time. It is, in effect, a complete solution of the differential equations, encompassing all transient and steady state motions. Nonlinear, and even discontinuous excitations and elements, are permitted in this kind of solution. The sample problem described previously is an example for which a time-varying solution was produced.

The second type of solution generated by the Dyana compiler provides frequency response information on the behavior of a system. Here the equations of motion of a problem are transformed into complex linear-algebraic equations, and the amplitude and phase of every point in the system are computed at prescribed values of the excitation frequency. This is essentially a steady state solution of a problem and its use is limited to linear systems excited by sinusoidal forces. It is a practical solution whenever resonant conditions are being investigated.

To Order Paper No. 127D . . .
. . . on which this article is based, turn to page 6.

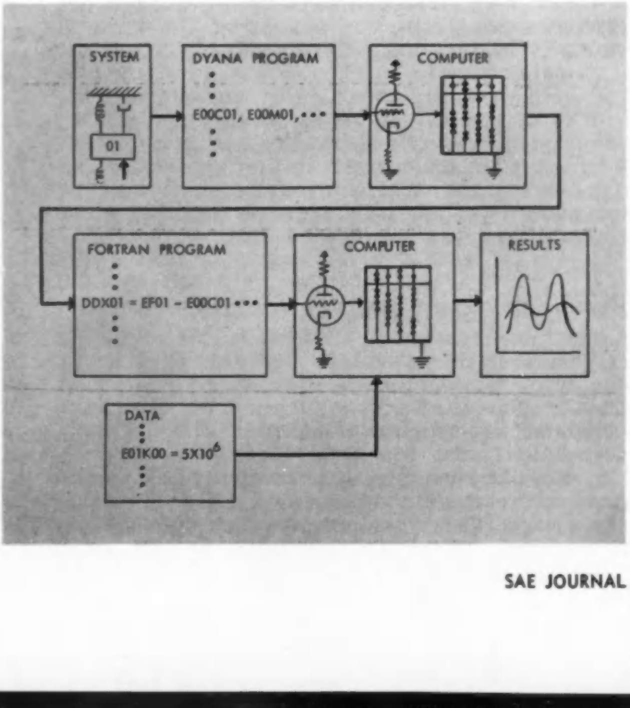


Fig. 2—Sequence of events in the Dyana solution of a problem.

Aircraft Nuclear Propulsion program brings useful byproducts:

• New uses for rare metal – yttrium.

• Radiation-tolerant electronic devices operable at elevated temperatures.

• High-temperature thermocouples.

D. R. Shoults
Member, SAE Nuclear Energy Activity Committee

THE development of nuclear propulsion systems for aircraft is bringing discoveries and advancements useful to both aviation and automotive industries. For example, during 1959 engineers and scientists engaged in the USAF and AEC aircraft nuclear propulsion program at General Electric Co.'s Aircraft Nuclear Propulsion Department, Cincinnati, Ohio, and near Idaho Falls, Idaho, reported on:

- Fe-Cr alloys containing yttrium to improve their high-temperature characteristics. (Yttrium is also reportedly showing promise as a reactor material.)
- Electronic devices that can operate at 1000 F in a reactor's radiation environment.
- Refractory metal thermocouples that can operate at 4000 F.

New Uses for Yttrium

Yttrium possesses useful nuclear and metallurgical characteristics. This rare metal, chemically similar to the metals of the rare earths, has generally been regarded as a laboratory curiosity. Developments during the last several years have made it available in sufficient quantities for study by metallurgists and for use by reactor designers.

Pure yttrium has mechanical and physical properties similar to those of titanium and possesses a relatively high degree of "transparency" to thermal neutrons. (The nuclear physicists' term is "low absorption cross-section.") This means that yttrium can be used as a reactor core material because it allows thermal neutrons — fission products essential to the continuation of a chain reaction — to pass relatively unimpeded.

The addition of small amounts of yttrium has improved considerably the high-temperature oxidation resistance of iron-base chromium alloys. For instance, in AISI type 446 (SAE 51446) stainless steel containing 25% chromium, a 1% addition of metallic yttrium provides as much oxidation resistance at 2500 F as was provided by the original alloy at 2000 F.

By using 1% yttrium instead of 5% aluminum, the oxidation resistance of the alloy is attained without sacrificing its fine-grain structure. Other advantages of yttrium additives include improved workability of the alloy, grain refinement, and resistance to recrystallization at high temperatures.

Radiation-Resistant Electronic Devices Operate at 1000 F

The national space-exploration effort, the missile industry, and the atomic energy industry stand to benefit from the development of electronic systems for aircraft reactors. Much practical knowledge is being derived by electronics experts in producing systems to cope with high-temperature and radiation environments associated with aircraft nuclear propulsion systems. This advanced technology is applicable to electronic devices that must be capable of enduring the high temperatures of re-entry and the nuclear radiation fields that may be encountered in the Van Allen belts and in space.

First successful testing in radiation and high-temperature environments was accomplished in 1956 when an electronic circuit operated for 50 hr at 1000 F inside a materials test reactor; preceding this test was a 115-hr checkout at 1200 F. The de-

Nuclear Propulsion

. . . continued

vice, a 3-stage preamplifier, was subjected to a radiation dosage of 1.5×10^{17} neutrons per sq cm at the Oak Ridge National Laboratory. Circuit components included ceramic single-triode tubes, platinum leads spot-welded to tube elements, titanium-strontium resistors, and an alumina chassis.

Early tests indicated that a strong radiation field changes circuit characteristics by inducing leakage around high-value resistors and by decreasing resistance of capacitors to d-c voltages. Circuit design requirements therefore include limiting resistances and capacitances to low values (50,000 ohms, 0.01 microfarad maximums), avoiding organic materials, and adhering to simple circuits.

More recent tests involved a preamplifier that successfully incorporates more sophisticated circuits. Tests included operation at temperature extremes from −65 to 590 F, at simulated altitudes, and under high-humidity conditions. The device survived vibrations and mechanical and thermal shocks. Components again included ceramic tubes but incorporated nickel-clad copper leads arc-fused to tube elements, glass capacitors, wire-wound resistors, and a copper chassis clad with stainless steel.

Refractory Metal Thermocouples for 4000 F

Another dividend of the aircraft nuclear propulsion program is a thermocouple capable of use at 4000 F. Scientists and engineers engaged in rocket, missile, and nuclear activities believe the new thermocouple will permit the study of materials properties at still unexplored temperatures and marks a major step toward providing thermocouples capable of measuring temperatures of rocket exhaust gases.

The development resulted from a requirement for sensing the high temperatures used in the study of materials for aircraft propulsion reactors. Furnace control requirements, black-body calibration inaccuracies, having to sight through fumes and glass enclosures, and instrument bulk preclude the satisfactory use of optical and radiation pyrometers. The requirement of having to function in strongly reducing atmospheres prevented the use of existing thermocouples, even in lower temperature ranges. Combinations of tungsten, molybdenum, iridium, and iridium/rhodium were discarded in favor of a tungsten-rhenium combination that displayed high thermoelectric potential and power, very high melting points of thermocouple components, chemical stability in neutral and reducing atmospheres, and ductility of the rhenium leg and thermoelectric stability after cycling at elevated temperatures.

Refractory metal thermocouples are in constant use by the nuclear pioneers in applications requiring quick and precise determinations of high temperatures in nonoxidizing atmospheres. Sealed thermocouple assemblies have been successfully used for long periods in air at 2400 F.

Boeing 707 Landing Gear Problems . . . and Their Solution

Based on paper by

W. P. Ericksen

American Airlines, Inc.

KNOWLEDGE accumulated in only one year of operation of the Boeing 707 has led to better design and performance of the landing gear. Therefore, a review of the problems met and what was done to solve them should be helpful to future design and operation.

PROBLEM — The landing gear is made primarily of high strength steels to achieve light weight. Such steels are very susceptible to rapid fatigue cracking at stress riser or high stress areas that may be inherent in the design.

An outer cylinder developed a fatigue crack in a high stress area at the junction of the torque-arm lug to the outer cylinder. Initial observation of the damaged area would not lead one to suspect trouble, as changes in cross-section are quite uniform and edges are well rounded.

SOLUTION — These areas are now being rounded to a 0.5-in. radius and modifications are being made to get better load distribution. Moreover, an inspection has been made of numerous gears to locate any areas which are potential stress risers and may cause fatigue problems.

PROBLEM — At gear retraction, automatic brakes are applied, causing an abrupt stopping of the wheel.

Due to uneven braking action caused, perhaps, by improper bleeding or wheel momentum, the truck is made to pitch up and down. The snubber does not dampen this violent pitching sufficiently, causing the attach bolts to fail when internal stops are contacted with one free end. The snubber hangs down under the gear from its other attach point. The centering cylinder then exceeds its limits and damages internal parts, the truck rotates unrestricted and contacts portions of the inner cylinder to damage the truck beam. Damage in the form of dents is critical when they exceed a depth of 0.005 in. At this point internal fatigue cracks are likely to develop.

Additional damage may be caused during retraction by the dangling snubber, which may puncture the wall of the water tank located between the wheel wells. Plumbing lines also may be damaged or broken.

SOLUTION — Automatic braking pressures were reduced, better system bleeding procedures were introduced, snubbing action was improved, slings were used to support the snubber in the event of attachment failures, and centering forces of the centering cylinder were increased.

PROBLEM — The truck beam and its pivot bolt suffered galling. The pivot pins are not chrome plated but are finished with a dry film lubricant to reduce wear. These bolts are intended to be stationary in the truck beam, but a small angular movement between the bolt surface and the truck beam leads to severe galling. The initial galling develops quite rapidly on the bolt and the truck pivot bolt hole, then and progresses at a slower rate. Other areas have been found where pin joints have worn rapidly due to surface roughness.

SOLUTION — Replaceable bushings and chrome-plated pins with much smoother surface have been adopted. Replaceable bushings or bearings, even in nonrotating areas, are essential to reduce overhaul costs and expedite overhaul of gear components.

PROBLEM — Loss of fluid can very quickly affect the energy absorption ability of the 707 oleo. Such loss can be caused by tolerance accumulation reducing 0-ring squeeze, by dirt and contamination entering seal areas, through damage incurred by difficulty in installation, and by ovalizing of the outer cylinder. Scraper rings have been found rolled out of their recess in the packing nut.

SOLUTION — Seal installations have been revised. Improvements have been made in the design of the packing nut to prevent scraper ring roll-out. Maintenance personnel have been trained in the necessity of servicing struts by the pressure versus extension charts. When leakage of fluid or air occurs, it is given a fluid quantity check.

PROBLEM — Rapid buildup of tire temperatures due to long taxiing after landing and dragging the brakes have caused tires to blow apart.

SOLUTION — Installation of fuse plugs in the wheels to release air pressure at a predetermined elevated temperature, prior to tire bursting. At the same time, the mode of operation is discouraged.

PROBLEM — Blowing of fuse plugs due to excessive brake application.

SOLUTION — (1) Caution flight screws to cool brakes adequately between landings. (2) Require brake inspection after a rejected take-off, depending on the weight of the aircraft and speed at which brakes are applied.

PROBLEM — Brake linings have shown greater wear on the top than on the bottom on being inspected upon removal for overhaul. This is attributed to axle deflection.

SOLUTION — Tapered shims are being placed between the brake and the brake flanges to provide more uniform wear.

PROBLEM — Shimmy or vibration has been a major nose gear problem. Tire balance contributes to it, but the major cause is the accumulation of tolerances in the numerous joints between the lower torque arms and the steering cylinders. There are six pin joints through which loads must pass before being dampened out at the steering cylinder. Even normal fit tolerances permit some play in the system and, as bearing wear increases, the problem becomes more severe.

SOLUTION — Two-piece pins are being replaced with one-piece pins and tolerances are being reduced.

To Order Paper No. 139B . . .
. . . on which this article is based, turn to page 6.

Recommendations to manufacturers

► **Reconsider the use of ultra-high-strength steels to insure getting the best material available with respect to weight, reliability, and economy.**

► **Improve test methods to make them reflect actual operating conditions more closely. Use better methods to locate high stress areas which may cause fatigue cracking.**

► **Use hard-chrome-plated pins for all pin joints and replaceable bushings for all joints. The cost is less at time of manufacture than at overhaul. Give thought to ease of servicing, maintenance, and component replacement.**

Recommendation to operators

► **Give maintenance personnel adequate training in servicing and general maintenance procedures.**

► **Provide operating personnel with proper instructions and advise them of necessary precautions.**

► **Cooperate with the manufacturer to correct existing faults and prevent their recurrence**

How Do the COMPACTS Compare?

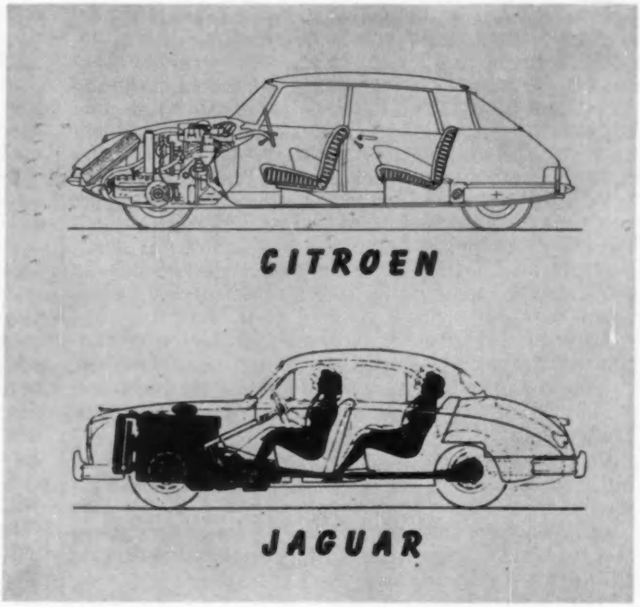


Fig. 1 — **Longitudinal cross-sections**

Based on paper by

John R. Bond

Publisher, Road & Track Magazine

THE PRESENT crop of compact cars shows a wide range of diversified thinking — both as to original purpose and resulting final product.

This can perhaps be illustrated adequately — and in a reasonable space — by comparing the six American compacts with a representative compact from each major importing country, such as the Peugeot from France, the Fiat from Italy, the Jaguar from Britain, and the Mercedes from Germany. (Our Swedish friends build a very eligible compact — the 4-cyl Volvo Amazon, but it had to be omitted in the interests of brevity.)

IN THIS FIRST OF THREE provocative articles, John R. Bond details objectively the differences and similarities in engineering design revealed by the 1960 world crop of compact cars. (Bond uses the generally accepted, but arbitrary definition of a "compact" as "any car with a wheelbase between 100 and 110 in.")

Bond is the man who did the outstanding, objective discussion of rear-engine cars for SAE Journal early in 1957 . . . when designers were still evaluating and experimenting with rear-engine designs.

NEXT MONTH (May) Bond's second article will be titled, "Suspension System Differences in the Compacts Are TREMENDOUS."

IN JUNE, the third and final article will give factual answers to the question, "Are the Compacts of the World in a HORSEPOWER Race?"

These have been selected from among the 22 cars coming within the generally accepted, but arbitrary definition that a compact car is one with a wheelbase between 100 and 110 in. Table 1 lists the main external dimensions of these 22 cars.

The table also contains dimensions for four cars with a wheelbase of more than 110 in. — and three of these have an external volume of less than 450 cu ft. Thus, these three are smaller in volume than the Rambler B, widely advertised as a compact.

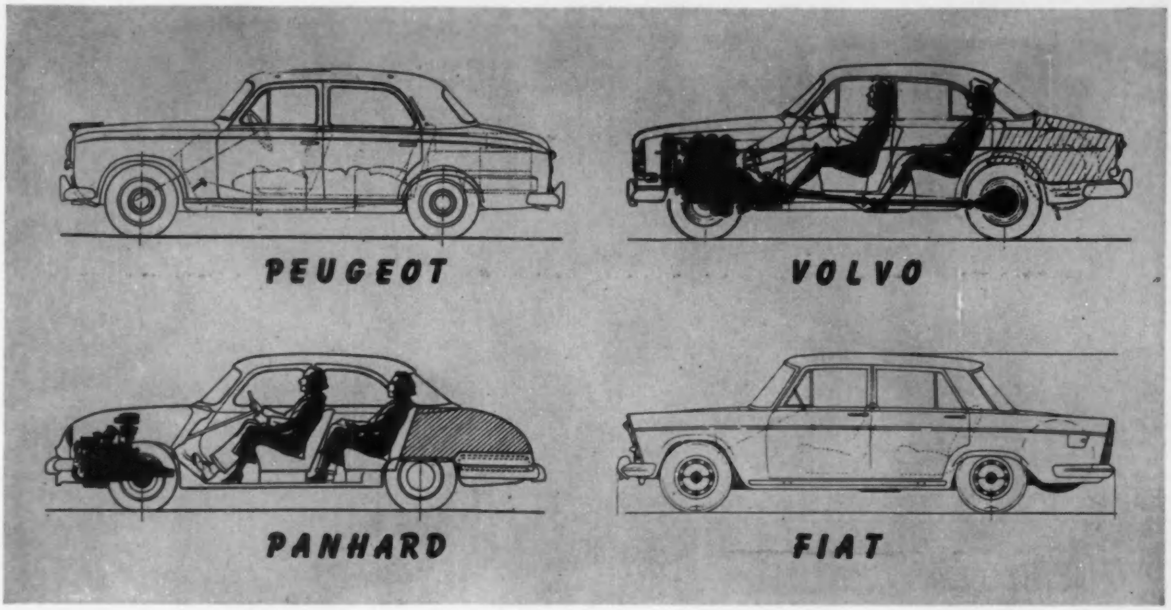
These have been added to show that the present definition of a compact is somewhat unfortunate because, although the word "compact" implies minimum overall dimensions, there are a number of cars with over 110-in. wheelbase, but with an overall length less than that of some cars generally called "compact." An example is the French Citroen, with 123-in. wheel base, but an overall length of only 189 in.

Seating package

All companies have paid a great deal of attention to the seating package, but the results are not terribly different, one from the other. One exception is the Corvair, where the designers chose to take full advantage of a unit engine-transmission assembly to get the lowest possible center of gravity and concomitant roof line. This seems to be a worthy effort to secure a safety and styling advantage at the expense of ease of entrance and exit. At least it will appeal to the young in heart, though possibly not to their stiffer grandparents.

Ease of entry

There are many ways of testing or comparing ease of entry, but one of the simplest is the ground



through six imported compact cars

to windcord measurement. Another factor is the step-over height. Table 2 gives these dimensions, plus floor height, all measured at curb weight and at the front door.

The average ground to windcord measurement (here) is 52.38 in., the extremes being 4.88 in. lower and 3.12 in. higher.

Another way to examine the seating package is to measure the utilization of space lengthwise, bearing in mind that *low seats require more legroom than do higher seats.* In Table 3, we find dimensions labeled *A*, *B*, and *C*. These are: *A* — centerline of front wheels to centerline of brake pedal; *B* — pedal to rear seat corner; and *C* — corner to centerline of rear wheels. The *B* dimension is, of course, significant and $A+B+C=$ wheelbase.

Many other ways and means of evaluating seating package efficiency are possible, and such things as tire size, tread, and seat height enter into the picture. It is noteworthy that the engine location doesn't make much difference in the *B* dimension.

Fig. 1 shows longitudinal cross-sections through a number of compact cars. The Panhard is shown because it is the only 2-cyl car in this category; also, it has the lowest coefficient of wind resistance — or "coefficient of penetration," as the French call it — of any production automobile. French magazines gave its C_w factor as 0.21, but there is reason to believe the actual value is closer to $C_w = 0.25$ — still most remarkable.

While styling is outside our province, the aerodynamic aspects of the automobile package are finally beginning to get the attention they deserve. Several firms have done some wind tunnel work, but they were all reluctant to publish the results. However, Table 4 presents a study based on coasting tests, with a few guesstimates thrown in. It would be interesting to see more accurate data made available. Incidentally, the weight figures used in this

Table 1 — External Dimensions of Cars

	Wheelbase, in.	Height × Width × Length, in.	External Volume, cu ft
1. CORVAIR	108.0	51.8 × 66.9 × 180	360
2. Borgward	102.4	53.2 × 67.7 × 173	361
3. Fiat 2100	104.3	56.1 × 63.8 × 176	364
4. Volvo Amazon	102.4	59.2 × 63.5 × 173	377
5. Opel Rekord	100.0	58.7 × 63.6 × 175	378
6. Ford Taunus	102.4	59.1 × 65.7 × 172	387
7. Peugeot 403	104.7	59.5 × 65.8 × 176	399
8. VALIANT	106.5	53.3 × 70.4 × 184	399
9. FALCON	109.5	54.5 × 70.0 × 181	400
10. Jaguar 3.8	107.4	57.5 × 66.7 × 181	401
11. Alfa Romeo	107.0	56.1 × 67.0 × 186	405
12. Panhard	101.2	61.0 × 65.4 × 180	415
13. LARK-6	108.5	57.5 × 71.4 × 175	416
14. Ford Consul	104.5	59.4 × 68.6 × 173	417
15. Mercedes 180	104.3	61.3 × 68.5 × 176	428
16. Mercedes 190	104.3	61.3 × 68.5 × 176	428
17. RAMBLER A	100.0	57.3 × 73.0 × 178	431
18. Simca V-8	105.9	57.4 × 69.7 × 187	432
19. Austin A-99	108.0	60.0 × 68.5 × 188	447
20. RAMBLER B	108.0	57.3 × 72.2 × 190	454
21. Humbler	110.0	61.0 × 69.8 × 185	455
22. Mercedes 220	108.3	59.4 × 70.7 × 192	467
Oversize			
1. COMET	114.0	54.5 × 70.4 × 195	431
2. Lancia V-6	113.0	57.5 × 68.9 × 191	438
3. Citroen	123.0	57.9 × 70.5 × 189	446
4. Rover 3-liter	110.5	60.3 × 70.0 × 187	457

How Do the

COMPACTS

Compare?

. . . continued

table are curb, plus 300 lb. Frontal areas were supplied by Corvair, Falcon, Valiant, and Lark; the others were computed by multiplying width by height by the factor 0.78.

Frames

Only one car on our list of 10 has a separate frame, and there is much to be said in favor of unit construction. But the average consumer doesn't care much which way his car is built, so

Table 2 — Dimensions Illustrating Ease of Entrance[a]
(All dimensions in inches)

	Floor Height	Step-Over Height	Windcord Height	Center of Gravity Height
Corvair	8.5	14.0	47.5	19.4
Falcon	11.2	14.2	51.4	20.0
Valiant	10.8	14.8	51.5	22.5
Lark 6	13.0	13.0	55.5	22.3
Rambler A	13.5	14.5	53.2	—
Rambler B	14.0	14.0	53.0	22.4
Peugeot	10.8	16.1	53.8	—
Fiat 2100	13.0	16.5	53.3	—
Jaguar 3.8	9.8	13.8	51.2	—
Mercedes	11.1	15.6	53.4	—

[a] All dimensions measured at curb weight and at front door.

Table 3 — Seating Package Evaluated by Means of Lengthwise Measurements

	Wheel-base, in.	*A*, in.	*B*, in.	C, in.	*B* as % of Wheel-base
Corvair	108.0	17.5	70.0	20.5	64.8
Falcon	109.5	24.2	71.2	14.1	65.0
Valiant	106.5	22.2	68.8	15.5	64.6
Lark	108.5	24.0	67.5	17.0	62.2
Rambler A	100.0	20.5	69.5	10.0	69.5
Rambler B	108.0	22.5	69.9	15.6	64.7
Peugeot	104.7	25.0	65.7	14.0	62.9
Fiat 2100	104.3	19.5	68.2	16.6	65.3
Jaguar 3.8	107.4	23.0	66.7	17.7	62.1
Mercedes	108.3	24.2	70.6	13.5	65.1

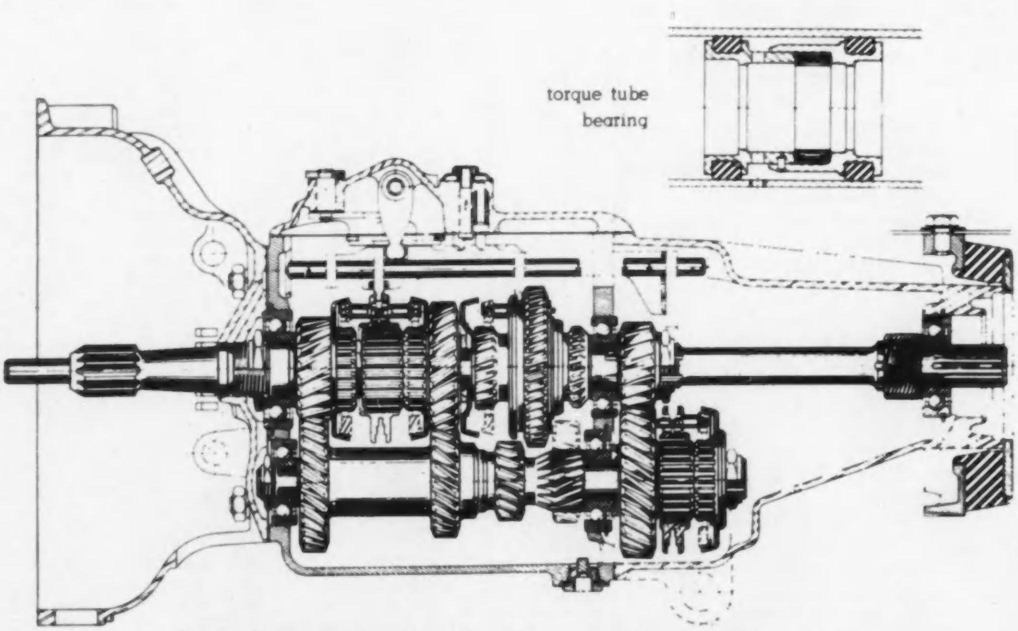


Fig. 2 — Unconventional gearbox of Peugeot has overdrive gear train at extreme rear.

it seems that the frame is still not obsolete. One completely new car from England (the Triumph Herald with a wheelbase of 91.5 in.) has a separate frame, which appears to integrate advantageously with its independent rear suspension.

The Ford Motor Co. has supplied some very interesting figures on body-in-white weights. Using certain yardsticks, as shown in Table 5, indicates that our weight-efficiency ratios are not yet as good as some European automobiles, though part of this can be blamed on our predilection for large overhangs at each end of the vehicle.

Steering

There is not much to say about the steering layouts of the various compacts except that the U. S. designs take too many turns of the wheel and too much space in which to turn. Table 6 shows the comparison better than words . . . and to build a car that is supposedly "compact" with a turning circle of over 35 ft is pretty absurd as well as disillusioning to the customer.

Transmissions

Of all the imported compacts, only the Jaguar and Humber offer automatic transmissions. Both use similar Borg-Warner units, manufactured in England. Four-speed, manual shifted gearboxes predominate; only the Consul, Taunus, Opel, Simca, Austin and Humber have three speeds forward. Of these, the Taunus and Simca are available with four speeds and the Opel has a synchromesh first gear. This latter feature is found on the following four-speed cars: Borgward, Fiat, Peugeot and Mercedes.

Overdrives are not very popular; they are optional on Jaguar, Austin, and Humber. However, the Alfa Romeo has five speeds forward with fifth operating as an overdrive and the Peugeot utilizes fourth gear as an overdrive by virtue of its 5.75:1 worm gear axle, which lends itself to direct drive in third. Fig. 2 shows the unconventional gearbox of the Peugeot, with its overdrive gear train at the extreme rear.

Clutches are much like our own, the exceptions being two options. Mercedes offers a hydraulic-coupling and Peugeot a Jaeger electric-particle clutch. Not many are sold, by the way.

The only unconventional rear axle is the worm drive by Peugeot. Fig. 3 shows the angular race type ball bearings used on the pinion shaft. Here the steel pinion is a quadruple thread and the worm is bronze with 23 teeth. The differential housing is aluminum and the side bearings are tapered rollers.

Brakes are, in general, much larger in area than those found on our cars and Al-Fin drums are used by Alfa Romeo and on some Mercedes models. A few British cars use disc brakes in front, but these require a booster and being an extra gadget, the booster can cause trouble. Fiat uses a hydraulic stepup cylinder.

To Order Paper No. 152B . . .
. . . on which this article is based, turn to page 6.

Table 4 — Aerodynamic Data

(Based, in part, on coasting tests)

	Frontal Area, sq ft	Tapley Drag, lb	Air Drag, lb	Calculated C_w	Corrected C_w
Corvair	19.2	127	74.5	0.435	0.42
Falcon	20.75	135	83.8	0.452	0.44
Valiant	22.0	138	80.0	0.417	0.41
Lark 6	23.3	145	84.2	0.421	0.45
Rambler A	22.6	145	90.0	0.446	0.46
Rambler B	22.4	170	107	0.529	0.49
Peugeot	20.7	127	74.5	0.394	0.42
Fiat 2100	19.4	145	89.0	0.510	0.50
Jaguar 3.8	20.7	130	61.5	0.330	0.38
Mercedes	22.7	132	71.2	0.352	0.48

Table 5 — Weight Efficiency Ratios

	Wheelbase (W), in.	Tread (T), in.	Body Weight (B), lb	Per Cent of Car Weight	$\frac{144B}{WT}$, psf
Renault	89.4	49.2	438	31.0	14.3
Volkswagen	94.5	50.8	530	34.5	15.9
Falcon	109.5	55.0	732	30.9	17.5
Corvair	108.0	54.0	767	32.6	19.0
Ford	119.0	61.0	1279	34.4	25.4

Table 6 — Steering Comparison

	Gear Ratio	Overall Ratio	No. of Turns	Turning Circle, Curb to Curb, ft	Ratio: Circle to Wheelbase
Corvair	18.0	23.5	4.8	39.5	4.39
Falcon	19.9	27.0	4.6	37.7	4.13
Valiant	20.0	23.8	4.5	37.1	4.18
Lark 6	Variable	Variable	4.4	37.5	4.15
Rambler A	20.4	22.0	3.9	36.0	4.32
Rambler B	20.0	23.0	4.7	37.3	4.15
Peugeot	—	16.5	3.7	31.0	3.56
Fiat 2100	—	—	4.0	37.7	4.33
Jaguar 3.8	—	—	4.3	33.5	3.74
Mercedes	—	—	4.1	37.4	4.14

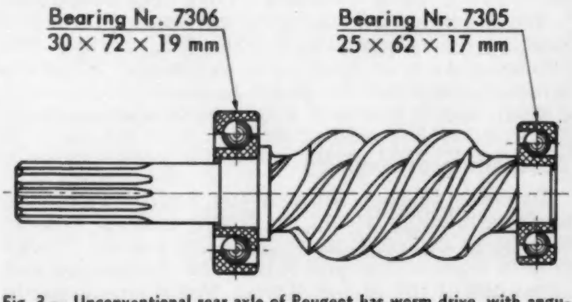


Fig. 3 — Unconventional rear axle of Peugeot has worm drive, with angular race type ball bearings on pinion shaft.

Revival of 1816 Stirling

produces quiet, efficient engine

This modern version of the Stirling

features high efficiency, low noise and vibration levels,

The present high weight and high costs are sure

are developed, making military and

Based on paper by

Gregory Flynn, Jr., Worth H. Percival, and F. Earl Heffner

General Motors Research Laboratories

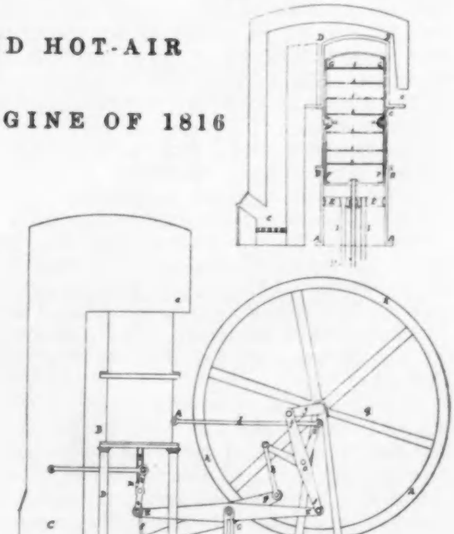
THE Stirling thermal engine differs from other modern engines in one major aspect. It is an external combustion engine. The fuel, the combustion air, and the products of combustion never enter the engine cylinder to become part of the working gas. On the other hand, the working medium is completely sealed within the active spaces of the engine and passes through the thermodynamic cycle repeatedly to cause the engine to operate. Heat is transferred from the combustion products to the working fluid through the metal walls of a heat exchanger, and heat is rejected from the working fluid through the metal walls of a second heat exchanger.

The Stirling thermal engine will operate from any heat source of sufficiently high temperature. Its efficiency is very high. Its sound and vibration levels are very low. Its power to swept-volume ratio is high, and its power to weight ratio is competitive.

Description of engine

In order to pass through the desired cycle, the working medium within the engine must be heated, it must be cooled, it must store and remove energy from a regenerator, and it must be compressed and expanded at the proper times. These requirements then prescribe the five major components of the

STIRLING'S REGENERATOR AND HOT-AIR ENGINE OF 1816



Engine Cycle

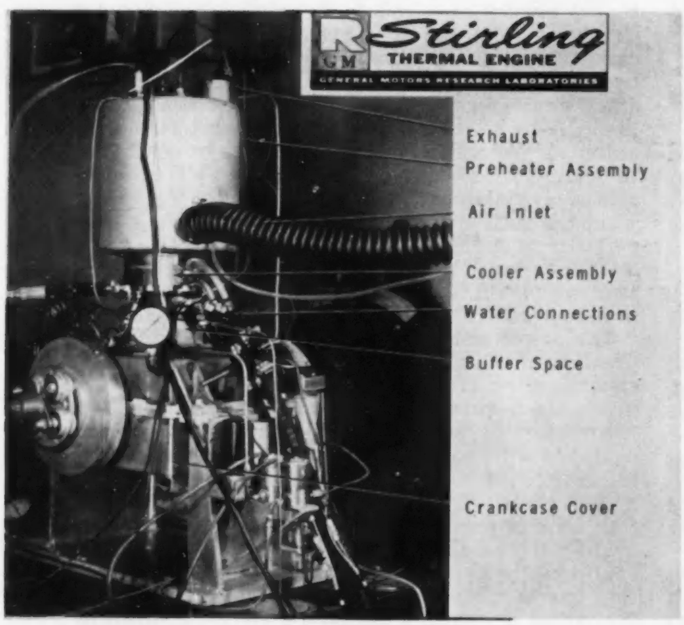
for 1960

closed-cycle external-combustion engine

and a clear, odorless exhaust.

to come down as production models

commercial applications feasible.



Stirling Engine

Old in Principle, New in Concept

THE MODERN STIRLING THERMAL ENGINE bears little resemblance to its historical predecessors . . . except in its principles, which have been known since 1816.

The modern engine has subtle qualities that can only be the products of present-day scientific and engineering skill. Most of the credit for this successful application of modern skills must go, the authors say, to the physicists and engineers of the Philips Research Laboratories of Eindhoven, Netherlands.

Philips' interest in the Stirling engine goes back to 1937, when the company was searching for a portable, silent engine having no radio interference, for driving small electric generators in remote regions.

The search narrowed down to the air engine, and the company obtained for test purposes several historic air engines operating on the Stirling cycle. The discrepancy between brake thermal efficiency and potential Carnot efficiency was so great that a research program was instituted to determine the reasons for the poor results.

Various engine configurations were built and tested during the ensuing years. Finally, efforts turned to the present single-cylinder, 2-piston type in which only one piston is loaded, as in Stirling's original 1816 patent.

Several cooperative programs were begun, including one, in 1946, between North American Philips in New York and the United States Navy Bureau of Ships.

During this same period, Philips began to work on a Stirling refrigerator. The resulting designs proved so successful that, by 1954, a fresh approach to the hot gas engine was taken, including the use of hydrogen as the working fluid, in place of air.

This resulted, by 1958, in Philips having achieved a brake thermal efficiency of 39% in a single-cylinder 40-hp engine. By then the company had also developed a 4-cyl 350-bhp engine.

About this time, GM Research Laboratories, which had been studying the Stirling engine, on its own, for about a decade, started a cooperative program with Philips to develop Stirling engines for American commercial and military applications.

Under this program the first two modern, full-size Stirling engines ever to operate in the United States were tested at the GM Research Laboratories in September, 1959. These engines had been built by Philips. It was primarily on the basis of their performance that GM Research decided to make a public introduction of this new prime mover.

The GMR Stirling thermal engine described here is a later configuration, representing a cooperative design of both Philips and GM Research.

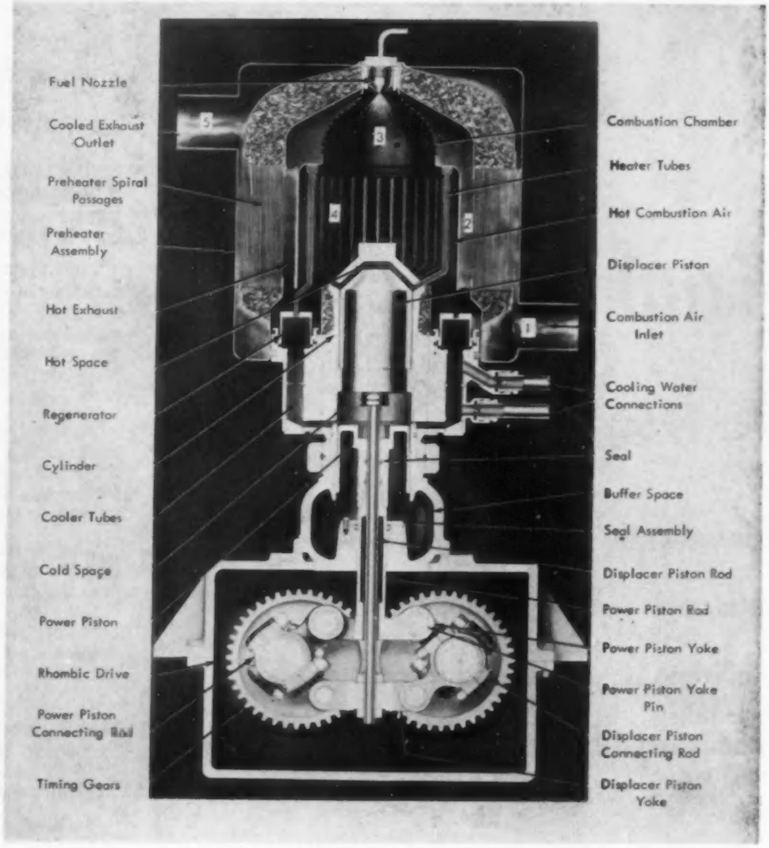


Fig. 1 — Schematic drawing of Stirling closed-cycle external-combustion engine. Five major components of engine are: engine heater and means of keeping it hot; regenerator; engine cooler and means of keeping it cool; displacer piston to control movement of working fluid through heater, regenerator, and cooler; and power piston to compress and expand the gas.

Stirling Engine

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Stirling thermal engine: (1) the engine heater and a means of keeping it hot; (2) the regenerator; (3) the engine cooler and a means of keeping it cool; (4) a displacer piston to control the movement of the working fluid through the heater, regenerator, and cooler; and (5) the power piston to compress and expand the gas.

The arrangement of these five major elements is shown diagrammatically in Fig. 1.

The **heater** consists of a bank of closely spaced stainless-steel tubes; brazed into the cylinder head, which form continuous gas passages between the cylinder head and the regenerator. These heater tubes are kept hot by burning fuel in an external combustion system.

The **regenerator** is a mass of fine wires sealed within eight individual cups located around the outside of the engine.

The **cooler** is formed from bundles of small tubes surrounded by an annular chamber through which water is circulated. These cooler tubes form gas paths from the regenerator back to the cylinder.

The **displacer piston** is simply a hollow stainless-steel shell, which fits loosely in the cylinder. Its motion is controlled through the displacer piston rod connecting it to the drive mechanism in the crankcase. There is very little pressure difference between the top and bottom of the displacer piston, and a small leakage of gas between the displacer and the cylinder wall can be tolerated; so this piston requires no piston rings or other means of sealing to the cylinder. The top of the displacer piston operates approximately at the temperature of the heater while the bottom operates approximately at the temperature of the cooler, so the piston walls are made as thin as possible to reduce conduction heat losses, and the piston has two internal, horizontal baffles to reduce radiant heat losses through the piston.

The **power piston** must provide the work of compression of the gas and it must deliver the work of expansion, so it experiences considerable pressure difference between its upper and lower extremities. It therefore fits more closely into the cylinder and is equipped with suitable rings or other sealing means to prevent gas leakage between the piston and the cylinder wall. The power piston is entirely in the cold zone of the engine. This allows more latitude in the selection of sealing means than do more usual engine pistons, which experience very high combustion gas temperatures. Force is transmitted from the power piston to a rhombic drive mechanism by means of the power piston rod, as shown. The power piston rod is hollow, and the displacer piston rod passes through it.

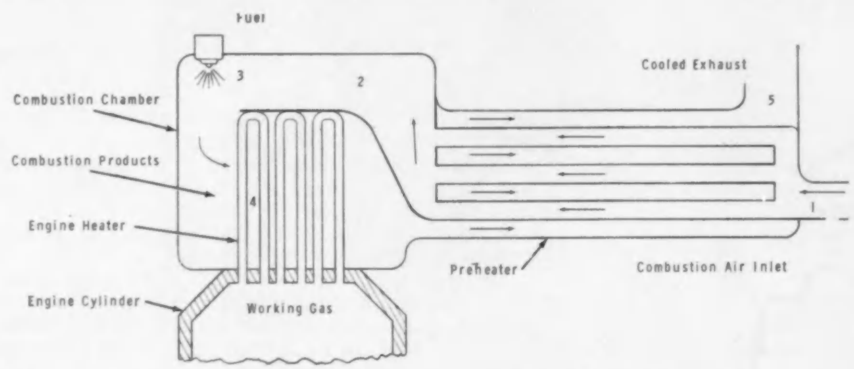

Fig. 2 — Schematic diagram of external-combustion circuit. The small numbers in the schematic circuit correspond to numbers in combustion gas circuit in Fig. 1.

Fig. 1 shows a buffer space below the power piston and above a seal assembly at the top of the crankcase. The engine is designed to operate at fairly high mean pressures, and the buffer space is provided so that a thermodynamically inert volume of working fluid can be trapped below the power piston. The mean pressure of this gas in the buffer space is kept near the mean pressure of the working fluid above the power piston and serves to reduce the loads on the drive mechanism. The GMR engine operates with mean pressures of the working fluid near 1000 psi.

The seal assembly shown at the power piston rod seals this buffer pressure while the crankcase is vented and operates at atmospheric pressure. It is also evident that a seal is required between the displacer piston rod and the inside of the power piston.

A schematic diagram of the external-combustion circuit is shown in Fig. 2. The essential elements of this external circuit are the preheater, which heats the incoming combustion air with heat from the departing exhaust products, the combustion chamber, where fuel is burned, and the engine heater tubes, through which energy is transferred from the combustion products to the working gas in the engine cylinder. Schematically, cold combustion air from a suitable blower enters at point 1. It is heated in the counterflow preheater, becoming hot combustion air at 2. Fuel is introduced by the nozzle and burned at 3, and the products of combustion give up energy to the working fluid in the heater tubes at 4. The exhaust gases then pass through the preheater, where they are cooled by the incoming air and exhausted at 5.

In the actual engine construction, these components of the external-combustion circuit are annular elements arranged symmetrically around the cylinder centerline. The counterflow preheater passages indicated in Fig. 1 are flat spiral passages that, with their headers and ducts, form an insulating assembly completely surrounding the hot parts of the engine. The exhaust gases flow outward through one set of spirals while the entering air passes inward through the alternate spiral passages. This preheated combustion air moves up through the headers and enters the combustion chamber. Fuel is introduced through an atomizing nozzle at the center top of the combustion chamber, and combustion takes place. The products of combustion pass radially outward and downward through the circular ring of closely spaced engine heater tubes and then out into the headers and spiral passages of the preheater. The cooled exhaust gas is then released through the exhaust outlet shown. The small numbers in the combustion gas circuit in Fig. 1 correspond to similar numbers in the schematic circuit of Fig. 2.

A cross-section of the actual combustion chamber is shown in Fig. 3. The burner introduces the atomized fuel from the nozzle into a vaporization chamber, where it is completely vaporized in an atmosphere much too rich to support combustion. This fuel vapor then passes into four swirl chambers. Here it is mixed with the heated combustion air, which enters the chambers through slots in their walls. Combustion is initiated in these swirl chambers.

Fig. 4 shows the heater tubes and the main engine cylinder assembly to which they are brazed. The two long tubes extending from the top of the heater assembly permit introduction of thermocouples, and the nut that clamps the cylinder assembly to the buffer space is also shown.

Rhombic drive mechanism

The motion of the pistons is controlled by the rhombic drive mechanism shown in Fig. 1. Fig. 5 is a view looking up into the crankcase with the crankcase cover removed.

The rhombic drive consists of two similar, contrarotating crankshafts with one crank on each crankshaft. These shafts are timed together by the pair of helical timing gears. The power piston is connected to the cranks by the power piston rod, the power piston yoke, and the power piston connecting rods. A similar series of parts connects the displacer piston to the crankshafts through the lower yoke and connecting-rod assembly. There are actually two power piston connecting rods on each crank, and they are spaced by the yoke to serve as a single, split connecting rod. The lower, displacer piston con-

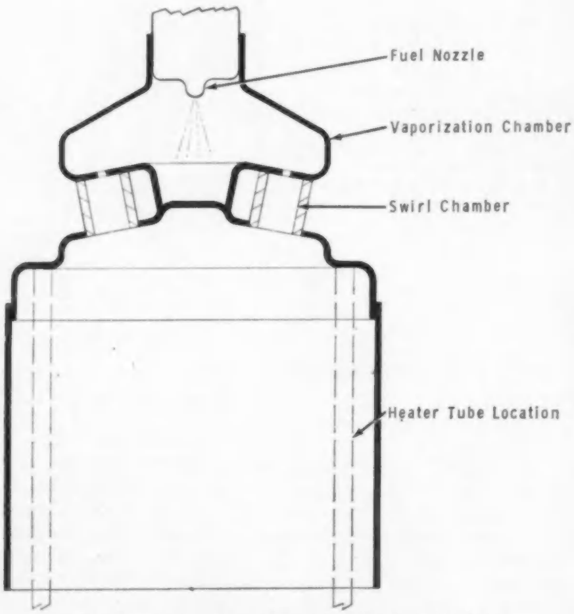

Fig. 3 — Cross-section of actual combustion chamber.

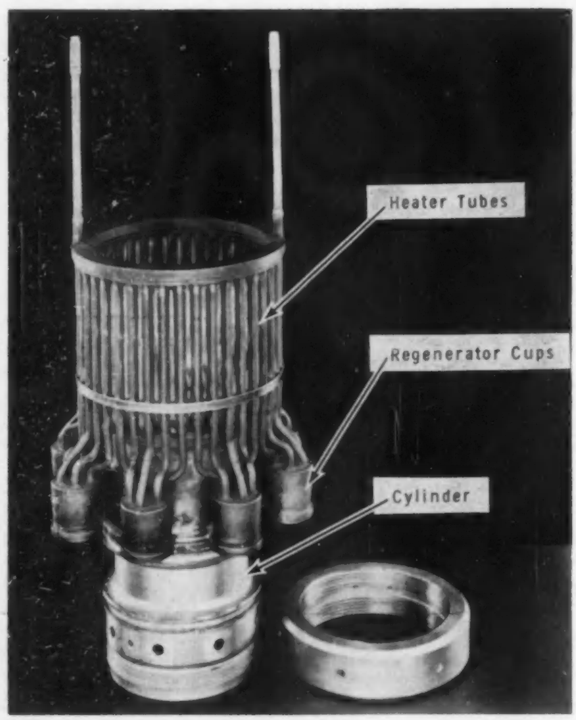

Fig. 4 — Heater tubes and main engine cylinder assembly to which they are brazed.

Stirling Engine

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necting rod then fits on the crank between the two power piston connecting rods.

The drive mechanism assembly is shown in Fig. 6. On the left the cranks are at their innermost positions and the pistons are closest together, while on the right the cranks are at their outermost points and the pistons are farthest apart.

An important feature of this drive mechanism is its symmetry of construction which permits complete dynamic balancing of all the moving parts of the engine by means of suitably located and sized counterweights on the crankshafts.

Engine operation

The operation of the Stirling thermal engine is completely governed by the relative motion of the two pistons, and it is most easily described by considering these piston functions.

It is evident from Fig. 1 that all of the working fluid is contained in the total volume that is the sum of the volumes of the engine's five working spaces and their short connecting pasages: the variable volume of the hot space in the cylinder above the displacer piston, the internal volume of the heater, the gas volume of the regenerator, the internal volume of the cooler, and the variable volume of the cold space between the pistons in the cylinder. The total volume occupied by the working fluid is, therefore, completely governed by the position of the power piston. Since the displacer piston always occupies the same volume, its position cannot change the total volume of the system. Thus, gas volume change to effect its compression or expansion is accomplished by motion of the power piston and is independent of the position or movement of the displacer piston.

On the other hand, the displacer piston serves to control the location of the gas within the total volume established by the power piston. When the displacer piston is at the top of the cylinder, most of the gas is in the cold spaces. Downward movement of the displacer piston forces the gas through the heat exchanger circuit upward through the cooler, regenerator, and heater into the hot spaces. The net effect of this downward motion of the displacer piston is to move most of the gas up from the cold space to the hot space. Moving the displacer piston down heats the gas. Reverse motion of the displacer piston upward from the bottom of its travel transfers most of the working fluid from the hot space downward through the heater, regenerator, and cooler into the cold space, and thereby effects a cooling of the gas.

Thus, the primary function of the power piston is to compress and expand the working fluid, and the primary function of the displacer piston is to heat and cool the working fluid. It must be emphasized that only the gas contained in the active spaces above the power piston goes through the thermodynamic cycle that converts part of the heat from the heater into work at the power piston. The gas contained in the buffer space below the power

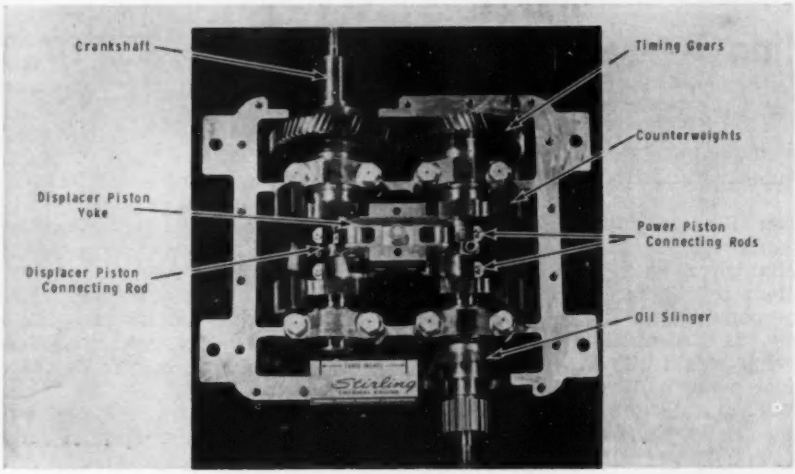

Fig. 5—Rhombic drive mechanism, which controls motion of pistons. (View with crankcase cover removed.)

piston is the same kind of gas as the working fluid, but it accomplishes no thermodynamic purpose and serves only to balance the forces of the mean pressure of the supercharged working fluid.

The ideal Stirling cycle is usually described by the sequence of piston positions shown in Fig. 7a. The ideal *PV* diagram is shown in Fig. 7b. In position I, the power piston is at bottom dead center (BDC), and the displacer piston is at top dead center (TDC). Thus, the gas is contained in the cold space at maximum total volume. The first process in the ideal cycle is an isothermal compression from I to II, and this could be accomplished by movement of the power piston from BDC to TDC without moving the displacer piston. The next required process from II to III is a constant-volume heating of the gas. This could be accomplished by moving the displacer piston from TDC to BDC without moving the power piston. The third process is an isothermal expansion from III to IV, which could be accomplished by moving the power piston from TDC to BDC without moving the displacer piston. The cycle would then be closed by returning the displacer piston to TDC to cool the gas at constant volume.

The above ideal description of the piston motion is based on the postulate that heat is transferred into or out of the working fluid through the cylinder walls during the isothermal processes. It has already been shown, however, that the actual configuration of the engine is based on the premise that heating and cooling of the working fluid must be accomplished by suitable movement of the displacer piston. Thus, a more realistic picture of the piston motion required to produce the ideal Stirling cycle can be created by means of a piston relative motion diagram like that of Fig. 7c.

In this diagram the position of the displacer piston is plotted on the ordinate as a function of the position of the power piston as the abscissa. The TDC's are at the top and left, respectively. This diagram can be used to illustrate the individual effects of the piston motions when the pistons move simultaneously.

The diagrams of Fig. 7 are duplicated in Fig. 8 using the actual engine parameters. A comparison of the actual *PV* diagram of Fig. 8b with the ideal diagram of Fig. 7b shows that the four ideal processes of the ideal cycle do not seem to be even closely approximated by the actual engine. However, a comparison of the relative motion diagrams (8c and 7c) shows that the positions of piston top and bottom dead centers are clearly defined for both the actual and ideal engines. This correlation of cycle events and mechanical piston events allows comparison between the actual engine operation and the ideal cycle. The ideal cycle thus becomes a cycle of four piston events rather than of four processes, as shown on ideal *PV* diagrams. The following four events follow in order for both ideal and actual engines: I — BDC power piston; II — TDC displacer piston; III — TDC power piston; IV — BDC displacer piston. These four events are easily noted on the piston mo-

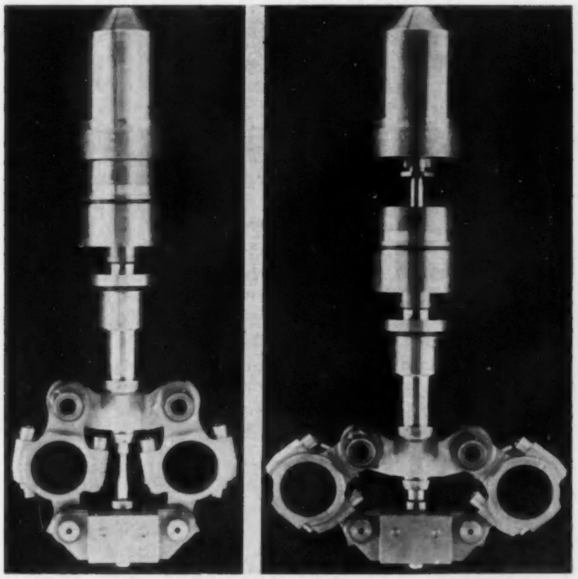

Fig. 6 — Rhombic drive subassembly. Left: cranks are at their innermost position and pistons are closest together; right: cranks are at their outermost points and pistons are farthest apart.

Stirling Engine

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tion diagrams, and they can be noted accurately on the actual *PV* diagram by equivalent crankshaft positions.

It is now possible to observe the actual engine piston movements and some of the compromises that are imposed by the real drive mechanism (Fig. 8c). The first compromise that is evident results from the impracticability of allowing the power piston to stop completely for part of the cycle. It is theoretically possible to conceive a drive that would allow this discontinuity, but any reasonable mechanism will not permit it. Thus, the vertical lines of Fig. 7c have been eliminated. It would also be impossible to stop the displacer piston during part of the cycle, but this is not required even in the ideal instance, as shown by the absence of horizontal lines in Fig. 7c.

Beginning at point I, the actual engine events can be traced in Fig. 8c. It is desired to accomplish isothermal compression from event I to event II, and the figure shows that the displacer piston moves in the cooling direction quickly at the beginning of this compression so that compression occurs with most of the fluid being cooled in the cold spaces, but cooling stops before the power piston reaches TDC. It is seen that the process from II to III is heating, as in the ideal cycle, but that it is accomplished at decreasing gas volume rather than at the ideal constant volume. The expansion from III to IV, however, is quite similar to the ideal. The pistons are moving down together, as indicated by the nearly straight 45-deg portion of the curve; and the downward motion of the displacer tends to keep the gas in the hot spaces, where it is heated, while the downward motion of the power piston accomplishes the expansion or power stroke. The final, cooling process is accomplished by an upward movement of the displacer piston while the power piston completes its travel to BDC.

The actual engine operations during the expansion and compression strokes are quite like those anticipated from the ideal considerations, with a relatively large time for heating during the expansion (III–IV) and a relatively small time for cooling during the compression (I–II). However, the long vertical lines that characterized the ideal diagram during the constant-volume, regenerative processes are not in evidence on the actual dagram. This difference is easily explained by examining the heat exchanger circuit in Fig. 1.

The figure shows the heater, regenerator, and cooler in a single, continuous passage, so that gas passing from the cold space to the hot space, for example, must pass through all three heat exchangers. It has been stated that the net effect of moving gas from the cold space to the hot space is to heat the gas. The truth of this statement is evident, and it is an adequate approximation of the major cycle event accomplished by downward motion of the displacer piston. It will be seen however, that some of the heat introduced into the working fluid during its upward movement is recovered from the regenerator since the cold gas passes through the regenerator before it enters the heater. The converse of this heat transfer takes place during downward motion of the gas through the heat exchanger circuit when heat from the heater is stored in the regenerator before the gas passes to the cooler and the cold space of the cylinder.

The difference between the actual relative motion diagram and the ideal relative motion diagram (Figs. 8c and 7c) can thus be explained. In the ideal diagram, the regenerative processes were clearly shown, because it was presumed possible to stop the power piston while these constant-volume heat exchanges took place. In the actual diagram the vertical lines are absent, because the power piston does not stop; but the regenerative process still takes place during the entire upward or downward motion of the displacer piston while the net cooling or heating is being accomplished.

The power output of the Stirling thermal engine is regulated by changing the *mass* of working fluid passing through the thermodynamic cycle. The cycle itself is not changed. A fuel control keeps the heater at a constant temperature regardless of the engine load level, and the cooler remains at a temperature near that of the available cooling water. The engine thus always produces a constant amount of work per pound of working gas, and the output is changed by changing the mass of working fluid in the active engine spaces. In the present GMR laboratory engines, this control is accomplished by supplying hydrogen from a high-pressure bottle, or bleeding working fluid to the atmosphere.

Advantages and disadvantages

The Stirling engine data given in Tables 1 and 2 are taken from General Motors Research tests on the original two engines brought to this country by Philips. The other data are from GMC tests on commercial engines. Performances of the engines at maximum economy and at full load are considered in each instance. The large engines all produce 30–40 hp per cylinder at full load, while the small engines are in the 6–9 hp per cylinder group. All except the Stirling engines are multiple-cylinder engines, and therefore are larger in total output.

Table 2 shows that the maximum thermal efficiency of the Stirling engine is greater than that of either of the other two engines, but that the efficiency of the Stirling engine falls slightly below that of the diesel at full load conditions. The automotive engine selected for this comparison produced thermal efficiencies about 4% greater than the average of all similar engines for which data were available. The diesel engine is one specifically designed to give maximum economy of operation.

The full load data show the Stirling engine to be slightly heavier, per horsepower, than the diesel, and that both of these are considerably heavier than the automotive engine.

The Stirling engine is thus seen to be similar to the diesel engine in efficiency and specific weight; and it is more efficient, but heavier than an automotive engine.

The small engine data of Table 1 again show the Stirling engine to have the highest maximum thermal efficiency as well as the highest efficiency at full load. In these small engine comparisons, the Stirl-

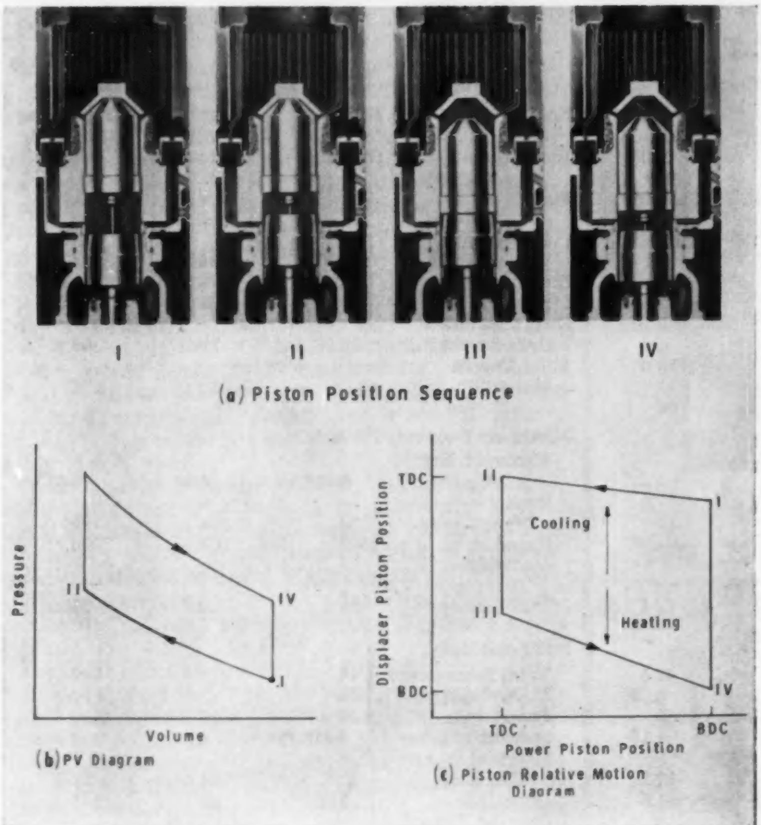

Fig. 7 — Ideal Stirling-cycle diagrams.

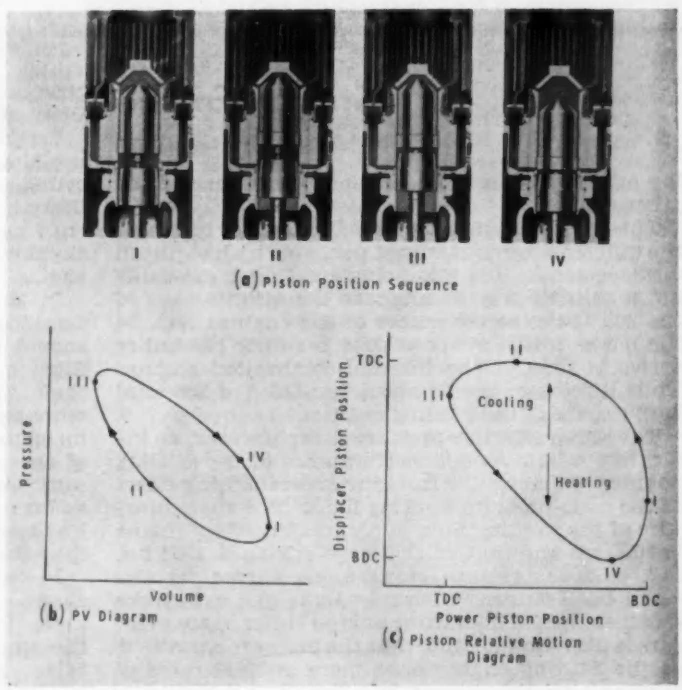

Fig. 8 — Actual Stirling-cycle diagrams.

Table 1 — Small Engine Comparison

Engine	Stirling	4-cyl gasoline	6-cyl outboard
Ideal Cycle	Stirling	4-stroke otto	2-stroke otto
Fuel	Diesel No. 1	Isooctane	Gasoline & oil mixture
Fuel Heating Value, Btu/lb	18,200	19,160	18,900
Bore, in.	2.36	2.50	2.44
Stroke, in.	1.33	2.25	2.13
Displacement/Cylinder, cu in.	4.94	11.0	10.0
Total Engine Weight, lb	127	120	96
Maximum Economy Data:			
Minimum Bsfc, lb/bhp-hr	0.47	0.458	0.81
Brake Horsepower	5.98	21	29
Speed, rpm	2400	3600	3500
Maximum Thermal Efficiency, %	29.6	29.0	16.6
Full Load Data:			
Total Horsepower	8.63	25.6	48.5
Hp/Cylinder	8.63	6.4	8.09
Speed, rpm	3600	4000	5200
Bsfc, lb/bhp-hr	0.528	0.51	1.10
Thermal Efficiency, %	26.4	26.1	12.2
Bmep, psi	192	115	61.5
Specific Weight, lb/hp	14.7	4.68	1.98
Specific Output, hp/cu in.	1.74	0.58	0.81

Table 2 — Large Engine Comparison

Engine	Stirling	6-cyl diesel	Automotive V-8
Ideal Cycle	Stirling	2-stroke diesel	Otto
Fuel	Diesel No. 1	Diesel No. 1	Gasoline
Fuel Heating Value, Btu/lb	18,200	18,200	18,900
Bore, in.	3.47	4.25	4.06
Stroke, in.	2.37	5.00	3.56
Displacement/Cylinder, cu in.	20.08	71	46.25
Total Engine Weight, lb	450	2190	678
Maximum Economy Data:			
Minimum Bsfc, lb/bhp-hr	0.358	0.40	0.415
Brake Horsepower	30	181	199
Speed, rpm	1500	1700	3000
Maximum Thermal Efficiency, %	39.0	34.8	32.4
Full Load Data:			
Total Horsepower	40	210	242
Hp/Cylinder	40	35	30.2
Speed, rpm	2500	2100	4600
Bsfc, lb/bhp-hr	0.418	0.41	0.468
Thermal Efficiency, %	33.3	34.0	28.7
Bmep, psi	317	93	113
Specific Weight, lb/hp	11	10.4	2.80
Specific Output, hp/cu in.	2.00	0.49	0.65

Stirling Engine

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ing engine is seen to be heavier than either of the other engines.

The Stirling engine is markedly superior to any of the others in terms of output per cubic inch of piston displacement. But this volume rating is probably not a suitable way to compare the effectiveness of the use of the active spaces of the engines because the power piston swept volume is nearly the entire active volume of the internal-combustion engines while it represents only about one-third of the total active space of the Stirling engines.

The mean effective pressure data, however, do indicate the high specific performance of the Stirling engines, which results from the supercharging effect of the high-pressure working fluid. The mean pressure of the working fluid in the small Stirling engine is 1000 psi and that of the large engine is 1500 psi. Fig. 9 gives pressure crank-angle curves for the small GMR Stirling thermal engine and a 2-stroke diesel engine. The Stirling engine buffer space pressure is also shown. Note that the pressure variations of the Stirling engine have more gradual rates of change and are less extreme in their total travel than are the pressure variations of the diesel.

It might be well to consider the effect of comparing single-cylinder Stirling engines against multi-cylinder otto and diesel engines. In the larger sizes, there is probably not much effect on the performance parameters shown in the tables except for a slight weight disadvantage for the single-cylinder engine.

In the smaller sizes parasitic effects are more significant and the total output of the engines should be considered. It will be seen that the 8.6-hp Stirling engine has better thermal efficiency than the highly refined, 4-stroke-cycle, 25-hp engine, and more than double the efficiency of the 2-stroke, 48-hp engine. Experience would indicate that, if either of the latter two engines were scaled down to the same total output as the Stirling engine, they would suffer a loss in efficiency from that shown. The 40-hp Stirling engine of Table 2 is much more efficient than the larger power otto engines of Table 1.

In the small engines, as in the large units, the single-cylinder engine suffers a weight disadvantage. It is difficult to to judge the extra weight of the small Stirling engine quantitatively from the tables, however, because the Stirling engines shown

are laboratory test engines, which were constructed with no attention to weight reduction, while all of the other engines are commercial products of sophisticated design from which all excess weight has been carefully removed.

Along with its inherently high efficiency, the comparatively silent operation of the Stirling engine is its greatest asset. The mechanism of the engine can be completely balanced for one or more cylinders at any speed. This characteristic is indeed unique to the Stirling engine. Also, there are no valves, with their attendant valve train noises, and no sharp pressure pulses to excite noise and vibration.

During operation, the most evident noise is that of the timing gears on the crankshafts. The larger Stirling engine sounds very much like an electric motor when operating under load, while the smaller engine is somewhat noisier, due to the higher operating speed.

The capability of the Stirling engine to operate from a wide range of fuels or from another type of heat source is evident. In special circumstances, this characteristic would prove of significant advantage. On the other hand, the laboratory Stirling engines produce cool, colorless, odorless, carbon-monoxide-free exhaust when operating on No. 1 diesel fuel.

Some of the disadvantages of the Stirling engine become apparent when the complete powerplant and its accessories are considered. First, most of the heat rejected from the Stirling cycle is rejected to the cooler with very little leaving to the atmosphere through the exhaust gases. Thus, the engine requires a larger radiator than the internal-combustion engine, but the high efficiency of the Stirling engine tends to minimize this effect. It is estimated that it would require a radiator about 2.5 times as large as that of an automotive engine for the same shaft horsepower.

In addition, the Stirling engine requires a blower to force the air through the preheater and the combustion chamber. This blower constitutes a parasitic power loss and could well be a significant source of noise. Here again, the high basic efficiency of the engine allows some compromise. In circumstances where the ultimate maximum efficiency is not required, the blower noise and power can be diminished by reducing the flow loss and the effectiveness of the combustion air preheater with an attendant loss in overall engine economy.

It is also evident that the Stirling engine will cost appreciably more than other modern engines, primarily because of the complexity of the heat exchanger construction required. The heater is constructed of small stainless-steel tubes, which must be carefully spaced to achieve the optimum heat transfer configuration and which must be carefully brazed to form hydrogen-tight joints under high-temperature operating conditions. The cooler must likewise be hydrogen-tight, but it operates at very low temperatures and is, therefore, less costly to construct. The complete balance and careful piston timing achieved by the rhombic drive are obtained at the expense of considerably more mechanical complexity than that of a simple crank mechanism.

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. . . on which this article is based, turn to page 6.

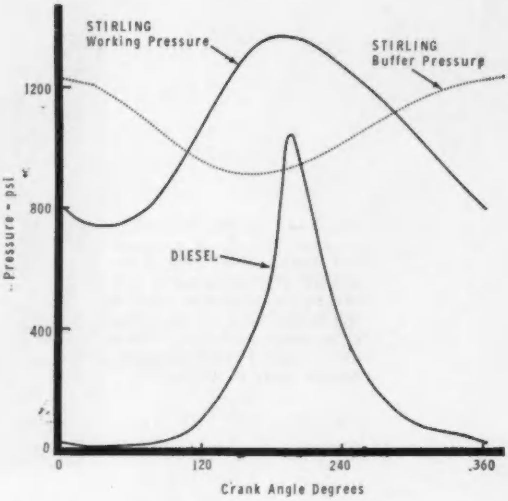


Fig. 9 — Pressure crank-angle curves for small Stirling engine compared with those for 2-stroke diesel engine. Note that pressure variations of Stirling engine have more gradual rates of change and are less extreme in their total travel than are those of diesel.

Does the Stirling Engine Have a Future?

THE modern Stirling engine will fit in with the other prime movers of the future about as follows, according to the authors:

For large installations, weight and efficiency will be at least as good as those of high-economy diesels. The Stirling engine would be used where quiet operation, invisible, odorless exhaust, or use of special fuels or heat sources warranted additional cost.

In small engine installations (10 hp or less), it would be used where its significant efficiency and noise advantages compensated for extra weight and cost. Here also the special fuel capability and clear exhaust would serve as advantages.

Such advantages would also make the Stirling engine most attractive for certain military applications. For example, GM Research is currently building for the United States Army Engineer Research & Development Laboratories, a 3-kw ground power unit that will drive a 60-cps electric generator for some military application. This portable, silent ground power unit will consist of a Stirling engine, the engine cooling system, and all necessary operating auxiliaries, including the fuel tank and controls.

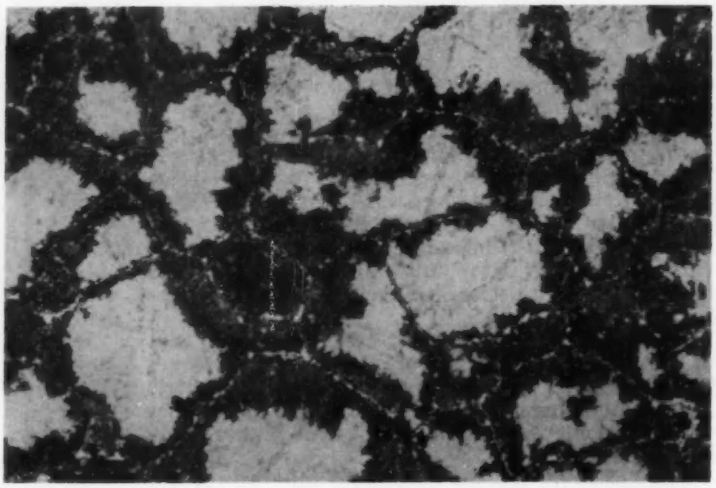


Fig. 1—Steel No. 315 carburized at 1800 F, oil quenched and tempered at 1000 F for 100 hr. Nucleation and growth of a transformation product starting at the grain boundaries in an austenitic matrix. (Nital etch, reduced from microphotograph taken at 1000 ×)

Research in antifriction

Heat-Treatment of

Based on paper by

O. W. McMullan

Bower Roller Bearing Division, Federal-Mogul-Bower Bearings, Inc.

ADVANCES in heat-treating high-alloy steels have resulted from a search to find better antifriction bearing materials. Some of the objectives of this search were to develop a steel that would:

1. Contain the more readily available alloying elements.
2. Carburize readily to a sufficiently high percentage of carbon.
3. Have a composition that could be carburized and hardened in production-type furnaces.

These objectives served as restrictions uncovering several metallurgical problems.

Most commercial high-temperature steels contain the carbide-forming elements, chromium, molybdenum, vanadium, and tungsten. These gamma loop closing elements raise heat-treating temperatures. Some of these steels, containing as little as 3 or 4% chromium, would not carburize uniformly at 1700 F. Some spots had no increase in carbon on freshly cut, clean surfaces, whereas rolled or forged surfaces did carburize uniformly. The formation of a green chromium oxide apparently served as an effective stop to carbide penetration.

Nickel makes contribution

Since aluminum and silicon impart certain adverse characteristics, molybdenum was chosen to impart hot hardness. Chromium was found to have an additional effect in this combination. With these carbide formers present, carburizing was slow and carbon content unsatisfactory at normal carburizing temperatures. When nickel, the most effective element for widening the loop and decreasing temperatures, was added, production of a uniform high carbon case was possible at temperatures of 1700–1800 F from the composition 315 containing 2.97% Ni, 1.80% Cr, and 5.19% Mo. This steel has an alloy content sufficient to maintain a hardness of 60 Rc after tempering at 1000 F. Thus, nickel which is not carbide forming and is normally considered to be an element decreasing the rate of carburizing, was essential in producing a steel of higher alloy content that would carburize under normal conditions.

However, the nickel created another problem. The case tended to be completely austenitic with a Rockwell C hardness of 30 or less, even with a carbon content of 1.25–1.50%. The case of the quenched

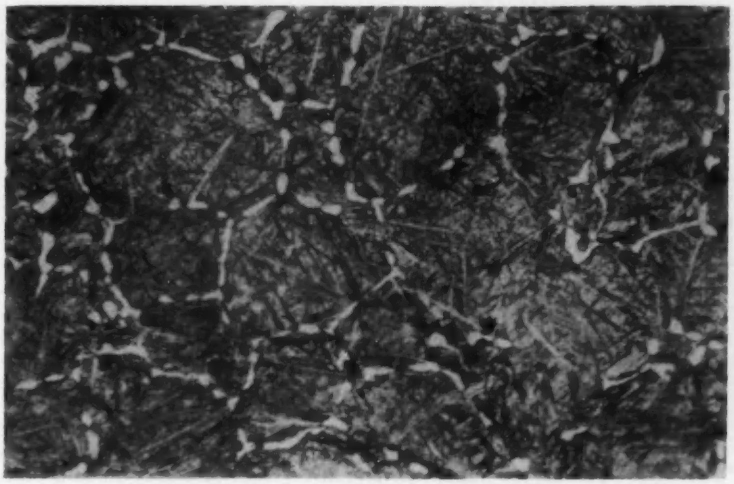


Fig. 2 — Same steel as shown in Fig. 1 except tempered six times to complete transformation of all austenite to martensite. (Nital etch, reduced from microphotograph taken at 1000 ×)

bearing materials advances

High-Alloy Steels

product was softer than the core as measured by penetration hardness, yet the surface could not be scratched with a good file. This gives evidence that, contrary to popular opinion, such an austenitic structure would have good wear resistance. Nevertheless, it cannot be tolerated in large amounts in bearings for two reasons: it is subject to plastic flow under load, which results in brinelling and dimensional changes, and it will transform to other constituents of larger volume under heat and stress and thus diminish dimensional stability. The elimination of the austenite posed the final problem in the heat-treatment of this case-hardened steel.

Elimination of austenite

Thermal treatments are used normally to decompose austenite. Single tempering proved unsatisfactory regardless of time or temperature either because of lack of transformation or the nature of the product formed. Periods as long as 100 hr at 1000 F produced only partial transformation by nucleation and growth, a globular decomposition product too low in hardness. Multiple tempering in periods of not more than one or two hours each, produced an acicular transformation product (martensite) with the required hardness. Fig. 1 shows

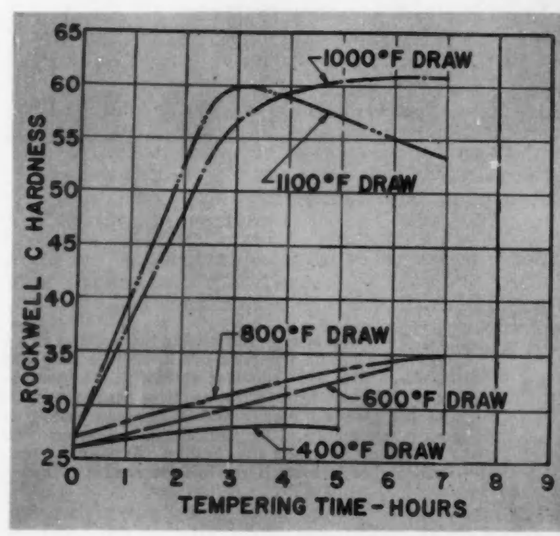


Fig. 3 — Case hardness of No. 315 steel carburized at 1800 F, oil quenched and multiple tempered in cycles of 1 hr at heat, intermittent cooling to room temperature. Tempering time represents both the number of cycles and accumulated tempering time.

Heat-Treatment of High-Alloy Steels

... continued

the microstructure after single tempering at 100 hr. Fig. 2 shows the fully transformed product obtained by multiple tempering.

Optimum temperature for multiple tempering depends upon the per cent and kind of alloying elements. The transformation curves for steel No. 315 (Fig. 3) show temperatures up to 800 F to be too low to cause little if any transformation, while 1100 F is so high as to cause undesirable softening of the reaction product. For this steel the best temperature was 1000 F.

Where transformation takes place

In multiple tempering it is important to know where transformation takes place — at the tempering temperature or on cooling therefrom — in order to determine the intermittent cooling temperature between heating cycles. The transformation in the quenched No. 315 steel could be followed readily because of the high percentage of austenite. Fig. 4 shows the conditioning effect in multiple tempering to occur only after cooling to some minimum temperature between heating cycles. This minimum depends on the stability of the austenite. Steels with stable austenite should be cooled to room temperature between heating cycles.

Another observation disputes the generally held impression that holding for a period of time or tempering a quenched steel prior to deep freezing stabilizes the austenite. This appears to be only a special case; the opposite or promotion of transformation is the common situation. If parts containing austenite are deeply frozen repeatedly with no intervening tempering, little or no transformation takes place after the first cooling. When tempered between freezings, both the heating and cooling causes further transformation, which then proceeds to completion in a relatively short time, as shown in Fig. 5. It is believed that this can be explained by a stress-relief theory, and that stabilization and conditioning are merely different manifestations of the same thing.

To Order Paper No. 122A . . .
. . . on which this article is based, turn to page 6.

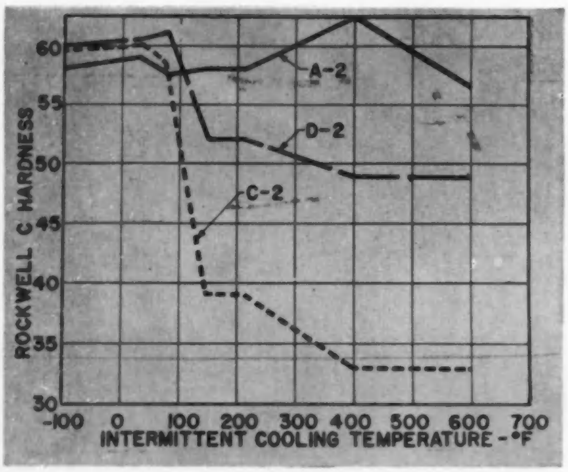


Fig. 4 — Effect of elevated cooling temperatures on the start of austenite transformation in multiple tempering cycles. Steels carburized at 1800 F, oil quenched and multiple tempered at 1000 F with intermittent cooling temperatures as shown. Readings taken at room temperature after completion of last cycle. Steel A2 containing 1.53 Ni, 1.24 Cr, 2.80 Mo; C2 containing 3.06 Ni, 2.85 Cr, 3.12 Mo; D2 with 2.97 Ni, 1.80 Cr, 5.19 Mo.

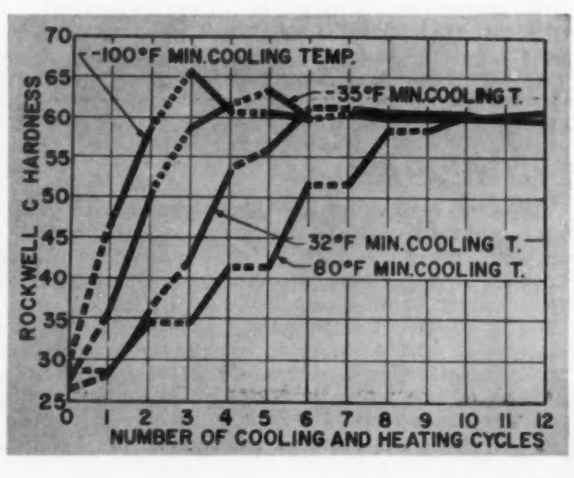
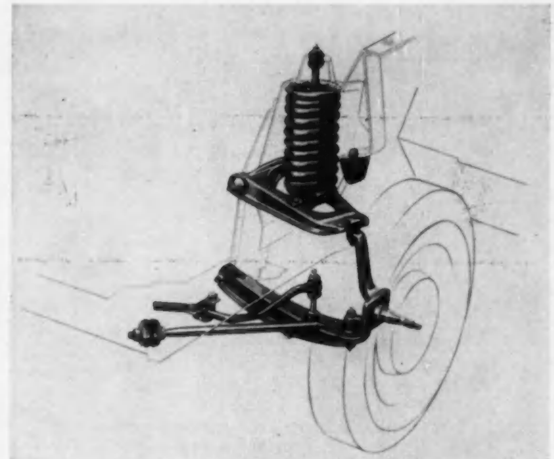


Fig. 5 — Effect of depressed cooling temperatures on the start of austenite transformation in multiple tempering cycles. Steel 315 carburized at 1800 F, oil quenched and cooled for 1 hr (at temperatures shown) between heating periods of 1 hr at 1000 F. Hardness readings at room temperature. Odd numbers show hardness after cooling, even numbers after heating. Accumulated tempering time in hours is one-half the number of cycles.

NOVELTIES in Falcon Suspension System



Novelties in the *Falcon suspension system* are in the front suspension, shown above. The spring is placed above the suspension arm . . . and the jounce bumpers are located over the upper ball joint. (The accompanying article tells *why*.)

Based on a paper by **Frederick J. Hooven and Robert R. Peterson** Ford Division, Ford Motor Co.

THE FORD FALCON suspension system, designed within specific cost and weight limitations, was developed to give this lighter vehicle as much as possible the comfort of its heavier companions.

Ride rates were chosen with an eye on the maximum tolerable change of attitude with load. The wheel rates, including tires, are 66 lb per in. in front and 86 lb per in. in the rear. The resulting vehicle frequencies are 77 in front, 91 in rear, with driver only. These change to 75 front and 80 rear with a 4-passenger load . . . and to 72 front, 77 rear with luggage and a 6-passenger load.

Placement of the spring over the suspension arm is the chief novelty of the Falcon front suspension. Otherwise it is of conventional SLA geometry.

The lower arm consists of a simple stamped lateral member, having attached a control strut running forward to a body cross-member. These together form the so-called "A" frame. This strut guides the lower part of the spindle support and absorbs longitudinal loads through rubber insulators.

Use of the spring in the unusual position over the suspension arm is seen as having four specific advantages as compared with the more usual position over the lower arm:

1. There is an appreciable saving in cost and weight because more efficient use is made of the chassis metal as structure.
2. Because the lower arm is unloaded, its stiffness and frictional resistance to longitudinal motion are reduced. Thus, suspension harshness is reduced.
3. The weight is carried in the upper ball joint, in compression. This avoids the need for either a compression joint in an inverted position, or a tension joint — one of which is necessary when the spring is carried on the lower arm. (Compared with either the compression or tension joint design, the Falcon design gives less pivot steering friction, lower cost and weight, and a smaller pivot offset.)
4. The upper, shorter arm can carry the spring bending loads with less added metal than would otherwise be required to be added to the lower arm. (The savings are much greater than the additional cost of the pivoted spring seat made necessary because of the greater angular motion of the upper suspension arm.)

Another novelty of the new Falcon front suspension is placement of the jounce bumpers over the upper ball joint, where the load is taken directly into the structure instead of by the suspension arm. This, too, provides a number of benefits as compared to the usual location of jounce bumpers on the lower arm some distance inboard of the outer joint. The benefits from this novel location include:

1. Relieving the suspension members of the secondary loads which develop with bumpers that act at some distance inboard of the outer joint. (This eliminates the extra weight and cost usually added to suspension members to avoid rough-road test failures.)
2. A much quieter ride on a rough road . . . because structural deflections do not result from secondary forces on jounce overtravel, and the car gives little audible sign that bumpers are coming into action.

Rebound limits are established by use of rebound cutoff-type shock absorbers.

Tests on various designs of front suspension joints resulted in selection for the Falcon of joints similar in principle to those used on the larger Ford cars. The angular travel necessitated a large ball joint throat opening . . . and this determined the ball diameter.

The Falcon rear suspension is a Hotchkiss-type, using 5-leaf springs. A degree of noise insulation is achieved by increasing the volume of rubber used in mounting the rear springs to the body — and by incorporating full-length butyl-rubber liners between the spring leaves.

To Order Paper No. S222 . . .
. . . on which this article is based, turn to page 6.

GMC V-6's and Twin Six Truck Engines

▶ **Family features high torque at low engine speeds, wide power range, and interchangeable components.**

Based on paper by

C. V. Crockett

GMC Truck & Coach Division, General Motors Corp.

A NEW line of truck engines, consisting of three V-6's (Fig. 1) and a twin 6, designed to deliver high torque at low engine speeds, has been developed by GMC. Displacements of the V-6's are 305, 351, and 401 cu in. while the twin 6 is 702 cu in. All four engines have the same stroke (3.58 in.) and the displacement is varied by changing the bore.

The 305 cu in. engine is intended for use in trucks of 5000–23,000 lb gross weight, hence three versions are produced. The A version is for light duty, the B version has heavy-duty valves and other changes to suit the heavier load, while the C version is a more powerful B.

While there is a wide displacement gap between the 401 and 702 cu in. engines, the gap in horsepowers is proportionately less than the difference in displacement because the 702 is governed at the very low speed of 2400 rmp.

Design advantages

At low speed, all engines deliver high torque, which decreases rapidly as the speed increases. High horsepower output has been avoided because it means high temperatures, with shortened valve life. And, too, high torque at low speed permits the use of a 5-speed transmission instead of the usual 8- or 10-speed type, hence there is less gear shifting required.

There are several reasons behind the production of the large 702 cu in. engine. They are:

- Possibility of operation at low specific horsepower output makes for durability.
- The high torque permits operation at low speeds in the interest of durability and silence.
- Normal operation at less than full power output decreases temperatures and improves durability and fuel economy.

Fig. 2 plots the 702 cu in. engine power output against the power required to pull 60,000 lb GCW, both being on a net output basis at the flywheel. It can be seen that, under stabilized conditions, the engine will be run throttled.

Why the V-6 configuration?

Several reasons prompted the selection of the V-6 and twin 6 engine types. A wide range of displacements can be had with few cylinders and without excessive cylinder size. Had less than 12 cylinders been used for a 702 cu in. engine, cylinder size would have been excessive. Moreover, the combination lends itself well to tooling interchangeability. Common tooling can be used for any machining involving the external dimensions of the engines, and for finishing cylinder bores and other boring or drilling operations parallel to the bores. To bore the twin 6, the front six cylinders are bored first then, in effect, the block is indexed forward and the operation repeated. The V-6 is economical to build and to service. In rebuilding and re-

Abridgment of an

SAE Detroit Section paper

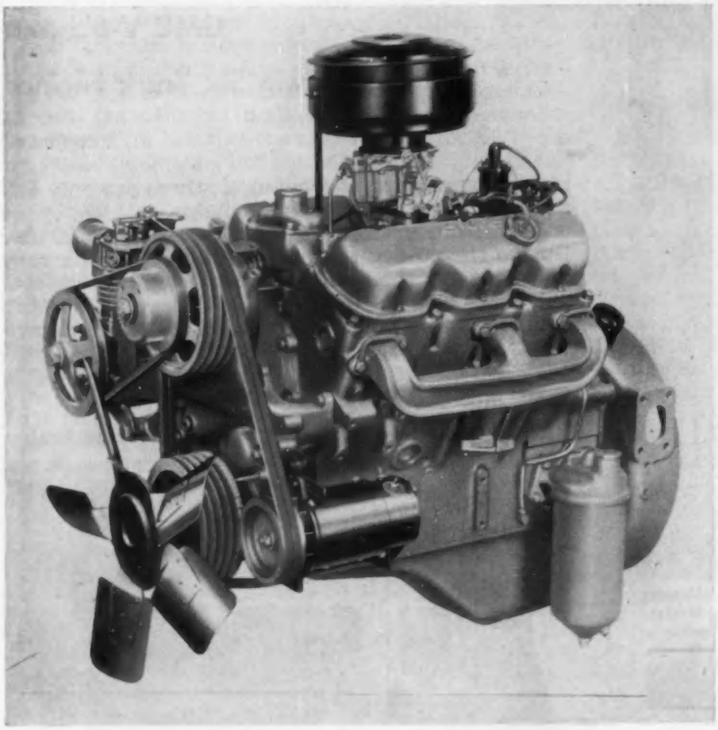


Fig. 1 — New GMC truck engine family includes three V-6's (one of which is shown above), and a twin 6. Engine banks have 60-deg angle, the left bank being staggered ahead of the right.

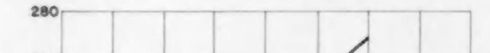


Fig. 2 — Power output of the 702 cu in. twin 6 plotted against power required to pull 60,000 GCW. The series of lines of equal specific brake fuel economy show that operation of the engine throttled along the power-required curve will give better specific economy than operation at full throttle.

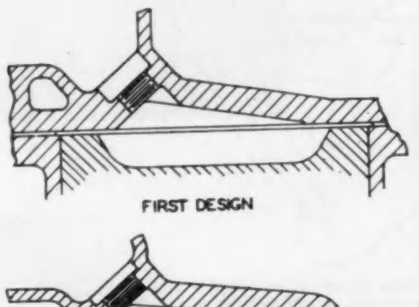


Fig. 3 — Cylinder head design development to attain a combustion-chamber shape giving good mechanical octane numbers. In the final design most of the chamber is in the head.

GMC V-6'S and Twin Six Truck Engines

. . . continued

placing worn parts, for example, there are only 6/8 as many parts as in an 8-cyl engine.

Engine dimensions are well adapted to truck use. Due to the 60-deg angle, both engines are narrow, and although the twin 6 is fairly long, it is narrow and low. The V-6 can be placed beneath a short cab; the twin 6 can project behind the cab and have the truck or trailer body extend over it.

Parts interchangeability

Seventy-three major parts are interchangeable

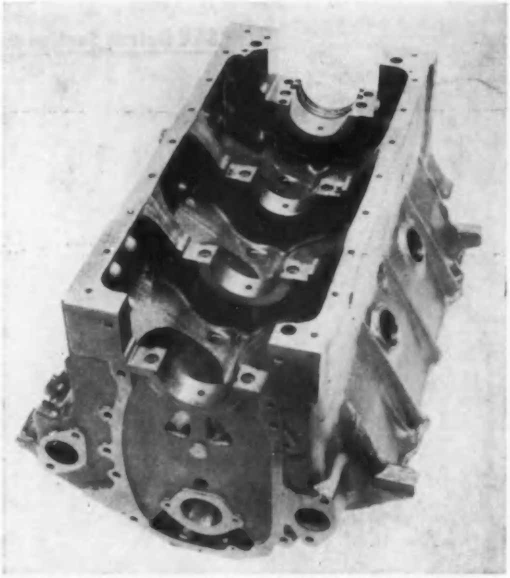


Fig. 4 — Inverted view of the cylinder block shows dropping of block rails 3 in. below crankcase centerline to increase rigidity of block and to provide greater depth at point of flywheel housing attachment.

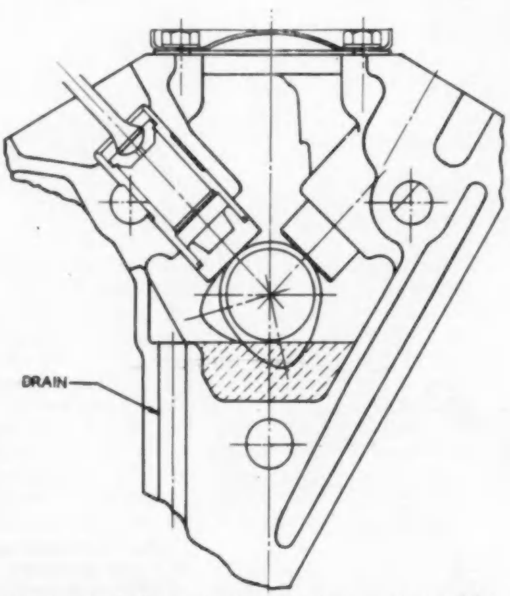


Fig. 5 — Camshaft operates in pocket to insure instant lubrication on starting. On running, oil splashes out of trough and cams are no longer submerged.

Table 1 — Total Water Flow
(Thermostat(s) open)

Engine	No. of Thermostats	Flow at 2400 Rpm, gpm	Flow at 3000 Rpm, gpm
305	1	116	141
351, 401	2	150	182
702	3	200	—

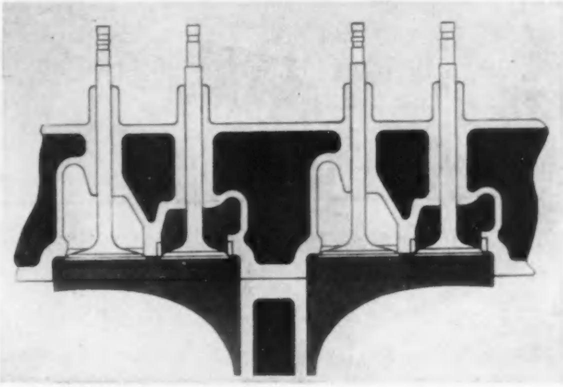


Fig. 6 — V-6 design affords large water spaces in cylinder head to insure good valve cooling. Bridge between intake and exhaust valves gives strong structure and provides room for exhaust valve inserts.

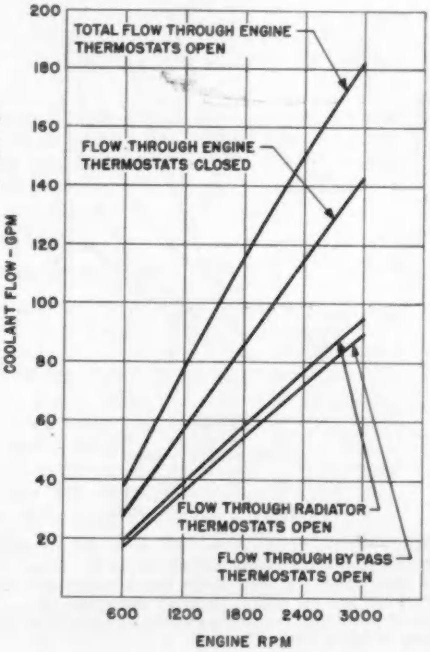


Fig. 7 — Water flow characteristics of the 351 and 401 cu in. V-6 engines.

among the V-6's and 56 among all the engines. Blocks are not interchangeable, but can be produced with the same tooling. Two cylinder heads and three sizes of pistons serve the line. Connecting rods are identical in all engines. Dimensionally and except for balance the crankshafts for all V-6's are interchangeable, but the 305 cu in. engine has a cast Armasteel crankshaft while all other engines use forged steel. Since the same crankshaft is used for the 351 and 401 engines, the piston assemblies must weigh the same to suit the crankshaft counterweighting. This is done by using a solid piston pin in the 351 and a tubular pin in the 401 engine.

Design development seeking to secure a combustion-chamber shape giving good mechanical octane numbers is shown in Fig. 3. In the final design, most of the combustion chamber is in the head. This is shaped as shown in cross-section and, in plan view, consists of an elongated oval formed by two circles joined by tangent straight lines. A portion of the chamber is in the saucer-shaped depression in the piston.

V-6 engine balance

Investigation of the inherent balance of a V-6 was conducted because the engine type is unusual. All primary forces due to reciprocating masses were found to be balanced and secondary forces were found to be small enough to be absorbed by the usual rubber mounts. Mathematically the linear motion worked out to be 0.0015 in. and this motion was confirmed by measurements by displacement pickups.

An inverted cylinder block casting is shown in Fig. 4 to bring out the dropping of the block rails 3 in. below the crankshaft centerline. This increases the rigidity of the block structure and provides a greater depth at the point of flywheel housing attachment to reduce deflection at this point.

The camshaft operates in a pocket. This is shown

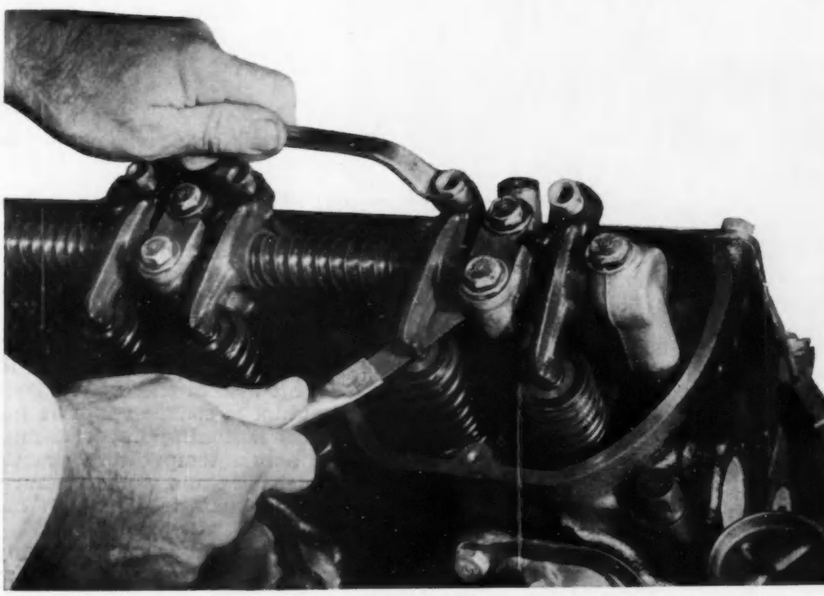


Fig. 8 — Self-locking screws facilitate adjustment of mechanical tappets on all model V-6 engines.

Fig. 9 — Valve pushrods and tappets can be removed by pulling tappet through clearance hole in cylinder head. There's no need to remove air cleaner, carburetor, and intake manifold.

in Fig. 5. When the engine is stopped, oil drains into the trough up to the height of the overflow drain holes. When the engine is restarted, the initial lubrication is available instantly, but after the engine is running, the oil is splashed out of the trough so that the cams cease to run submerged. This arrangement prevents tappet and cam scuffing during cold starts.

An important advantage of the V-6 engine is its shortness, which permits additional water spaces to be added in the head, as shown in Fig. 6. Moreover, the bridge between intake and exhaust valves provides a good structure and allows room for exhaust valve inserts. No two exhaust valves are adjacent. The valve guides are integral with the head casting, a design favored because of the improved heat transfer from valve to coolant.

Cooling characteristics

Experiments with this and other engines convinced us that valve durability may be improved by providing high-velocity water flow past the valves. Fig. 7 shows the water flow characteristics of the 351 and 401 engines. Water flow for all engines is shown in Table 1.

The water flow for the 702 cu in. engine is greater than that for the 351 and 401 engines, yet the volume has not been increased in proportion to the engine size. Since valve cooling is a function of water velocity rather than engine size, and since cooling water enters the rearmost head on each side of the twin 6 and proceeds forward through the rear head and then through the front head, the twin 6 area is identical with that of the V-6, therefore water velocity in the twin 6 will be the same as that in a V-6 at the same water flow. No greater volume of water is required for the twin 6. The larger engine has a greater total heat rejection, hence more water flow is provided through the radiator, and the total flow is greater when thermostats are open, but the total flow is not increased in direct proportion to the engine size.

These large coolant flows are realized with normal sized water pumps and without high pump horsepower by reducing the restriction to flow. This is accomplished in two ways — by a large bypass, and by opening up the bottleneck of the system, the thermostat, which in turn is done by using two or three standard size thermostats in parallel.

Adjustment of the mechanical tappets used on all V-6 engines is facilitated by the employment of self-locking screws, as shown in Fig. 8. Valve push-rods and valve tappets can be removed from the top without removal of the cylinder heads. The tappet is simply pulled through the large push-rod hole, as shown in Fig. 9.

In all engines except the 305A, crankcase ventilation tubes pass from each rocker cover to the intake manifold to give positive ventilation. The 305A has a road draft type of ventilation.

To Order Paper No. S228 . . .
. . . on which this article is based, turn to page 6.

Cesium Diode Can Convert Nuclear Heat to Electricity

Based on paper by

R. W. Pidd

General Atomic Division, General Dynamics Corp

THE TRUE potential of atomic energy can come close to realization with the use of plasma (or ionized gas) in combination with a nuclear reactor. The heat of the fissioning material can then be converted directly to electricity, in a system requiring no moving parts.

One device for producing the plasma is the cesium diode or converter, which can easily be adapted to reactor design. With this system the cesium lasts forever — only the uranium is consumed. The intrinsic temperature of the fissioning process is millions of degrees. The actual temperature practically, is limited by the melting point, vapor pressure, and other properties of the material of which the fuel is made.

The present plan is to operate at 2000 C — roughly twice as high as the operating temperature of reactors on the drawing board. The proposed temperature does, however, appear feasible on the basis of present laboratory data.

The thermodynamic efficiency of an engine working between 2000 C and room temperature is 87%. (Beyond this point, even great increases in temperature yield only modest advances toward the 100% limit.)

Power conversion efficiencies of up to 10–15% could probably be obtained with the present device. If this basic efficiency can be doubled, as most of those working in the field believe, the method will become competitive with conventional machinery.

How it works

The basis of the device is the cesium energy converter, which is a diode filled with cesium to provide high levels of ionization by the interaction of the cesium with the hot cathode, to form a plasma.

In some general respects, the cesium diode is a

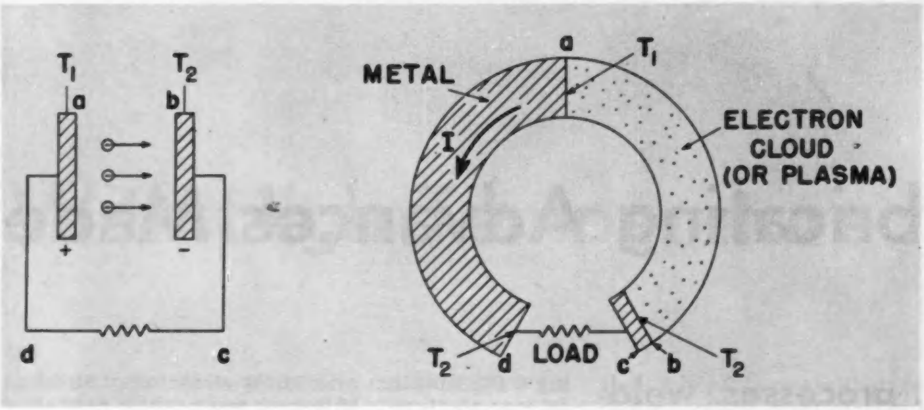


Fig. 1 — Cecium diode considered as a thermocouple. Left: cesium diode shown schematically as it actually is. Right: device shown, more abstractly, as a thermocouple.

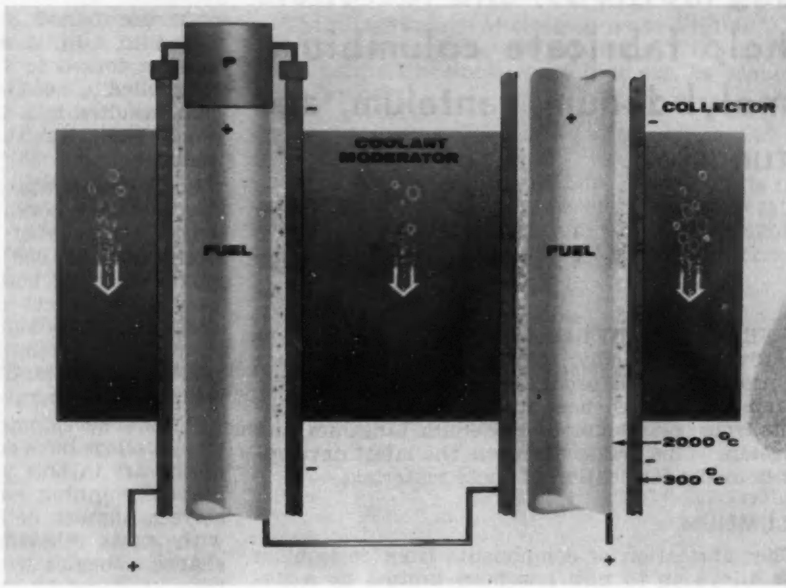


Fig. 2 — Reactor concept, in which fuel rod is suspended in container to which a very small quantity of cesium has been added. Fuel element design is shown here.

thermocouple. At the left in Fig. 1 it is shown schematically as it actually appears. A hot electrode emits current into the plasma region. This current is collected at the cold electrode and delivered to an external load. The device is shown at the right, more abstractly, as a thermocouple. The hot junction occurs at the surface between the coolant and the plasma. The cold junction occurs between the plasma and the cool electrode. The circuit is completed by the metallic leads joined to the load.

Portrayed in this way, it can be seen that the cesium diode is a thermocouple in which one metallic branch is replaced by the plasma. A thermocouple containing a plasma actually gives voltages as high as a thousand times those produced by an all-metal device. Thus, a 1000 C temperature difference gives one volt, as compared with the millivolt possible from perfect metals.

The cesium converter is adapted to reactor design in the following way. The fuel rod is suspended in a container to which a very small quantity of cesium has been added. Fuel element design is shown in Fig. 2.

Fuel rods containing uranium carbide have actually been driven to white heat in a configuration similar to this one, and electric power extracted. The collector must be cooled — as by water flow — to discard the waste heat.

The highest currents obtained so far in the laboratory have been 30 amp per sq cm of surface area, delivered at about one volt. This is an extremely high power density. A working area of one square foot would produce nearly 30,000 amp. In a heat-exchange reactor now being built for 40-mw operation, the exposed fuel element area is 5000 sq ft. With the new scheme this would produce 150,000,000 amp. Of course, in practice, such high currents would be quite useless. This figure only indicates the extremely high power levels that could be obtained today, even with the unimproved device.

To Order Paper No. 120A . . .
. . . on which this article is based, turn to page 6.

Fabricating Advances Made

▶ New alloys, processes, welding methods, and fasteners help fabricate columbium, molybdenum, tantalum, and tungsten.

Based on talk by

A. V. Levy and S. E. Bramer

Hughes Tool Co.

REFRACTORY METAL fabrication technology is advancing rapidly. New processing techniques for producing mill products now make it possible to fabricate large sheet metal structural components from columbium, molybdenum, tantalum, and tungsten. This article discusses the latest developments in the fabrication of these materials.

COLUMBIUM

The fabrication of components from columbium base alloys up to now has been limited by a deficiency of acceptable alloys in bar and sheet forms. Now, however, new alloys are becoming available for user evaluation. F 80 and F 82 are about the only columbium alloys commercially available today. Properties of the newer alloys are listed in Table 1; chemical compositions are given in Table 2.

Excellent room-temperature ductility and low room-temperature strength permits the F 80 and F 82 alloys to be easily fabricated. Sheet materials can be sheared and formed at room temperature by conventional equipment and techniques. Sound welds with room-temperature ductility are possible with the tungsten inert gas process and local gas protection.

The development of the new G. E. columbium alloys with their increased strength and lower ductility may require fabrication techniques similar to those developed for molybdenum to successfully produce required shapes.

MOLYBDENUM

Development quantities of sheet have recently been produced of a new molybdenum alloy containing 0.5% titanium and 0.07% zirconium. Successful manufacture of this sheet was possible only after refinement of present molybdenum production methods. The alloy sheet was produced as follows: arc-melted 8-in. diameter ingots were extruded to 4-in. diameter billets, the billets were hammer forged to 2 in. × 5 in. bars which in turn were rolled to 0.060 in. and 0.040 in. sheet. The program resulted in a 70% yield of good quality sheet which indicates that commercial production is feasible.

Room temperature tensile tests on the sheet in the as-rolled condition resulted in an ultimate tensile strength of 150,000 psi and a 0.2% yield strength of 130,000 psi. These properties are approximately 25% better than those of 0.5% titanium-molybdenum sheet in the same condition. The new alloy possesses about a 300 F advantage in elevated temperature strength over the 0.5% titanium-molybdenum alloy and has an increased 1-hr recrystallization temperature of approximately 2700 F.

Recent developments in forming sheet molybdenum alloys have considerably advanced the state-of-the-art in this area. Additional experience in manual spinning has resulted in documenting the correct number of intermediate break-down steps with stress relieving treatments to form various shapes. Joggles with a ±0.005 in. tolerance have been produced by spinning parts of revolution.

Although the new 0.07% Zr-0.5% Ti-molybdenum alloy has a higher yield strength than the commercially available ½% Ti-molybdenum alloy, the workability of the new alloy appears to be equal to or better than that of the commercially available alloy. In the work done to date on the new alloy it appears that the small zirconium addition has lowered the work hardening rate of molybdenum. This decrease in work hardening tendency allows the metal to flow more freely during forming so that more metal can be displaced per forming pass.

Fusion welds with room temperature ductility have been made on automatic welding equipment with filler wire alloy of 50% rhenium and 50% molybdenum. The molybdenum-rhenium filler rod makes repair welding of cracks in molybdenum alloy structures feasible.

It has been observed in some preliminary work that a weld joint containing molybdenum-rhenium filler metal is severely attacked by cementation-type oxidation-resistant coatings. This factor could limit the use of molybdenum-rhenium as a

With High Temperature Metals

ductile fusion weld filler alloy. Additional work will have to be done to verify this effect and to determine methods of counteracting it.

Electron beam welding is another method which might produce weldments with room temperature ductility in today's molybdenum alloys. Initial experimental work utilizing this process is now in progress but little data is available. The process employs localized bombardment of the material by a beam of electrons in a chamber having a very high vacuum. The use of electrons makes it possible to ionize embrittling interstitials such as oxygen and nitrogen which are present as compounds in the base metal. High purity weldments are obtained with oxygen and nitrogen quantities of less than five parts per million being reported. With a contamination level of this magnitude, weldments having room-temperature ductility should be possible.

The disadvantage of electron beam welding is the need for a high vacuum chamber. This requirement limits the size of part that can be economically welded.

TANTALUM

Tantalum has seen limited use because of its high cost, high density, and low elevated temperature properties. Alloying tantalum with columbium and tungsten, however, has proved relatively successful

Table 1 — Ultimate Tensile Strength vs Temperature of Various Columbium and Molybdenum Alloys

Temperature	Columbium — Ultimate Tensile Strength (ksi)						Molybdenum — Ultimate Tensile Strength (ksi)	
F	Haynes		G.E.		Du Pont	Westinghouse NC 31	½% Ti-Mo	½% Ti-0.07% Zr-Mo
	1	2	F 48	F 50				
RT		135	125	122	100		115	130
1200			90	93	71	79	82	110
1600			79	75	60	65	79	100
1800	53	37	73	64	48		77	95
2000	50	27	65	50	34	43	75	85
2200	47	20	51	35	25		60	77
2400	43	16	31	21	17		39	56
2600	41				10		22	38

Table 2 — Chemical Composition and Principal Alloying Elements of Various Columbium and Molybdenum Alloys

Columbium — Base						Molybdenum — Base	
Haynes		G.E.		Du Pont	Westinghouse NC 31	½% Ti-Mo	½% Ti – 0.07% Zr-Mo
1	2	F 48	F 50				
10% W	3% Al	15% W	15% W	10% Mo	5% Mo	0.5% Ti	0.5% Ti
5% Zr	3% V	5% Mo	5% Mo	10% Ti	5% Hf		0.07% Zr
		1% Zr	1% Zr				
		0.04 – 0.08% C	5% Ti				
		0.03 – 0.06% O_2	0.04 – 0.08% C				
			0.03 – 0.06% O_2				

High Temperature Metals

... continued

and it is in this role that tantalum appears to be best suited.

Commercially pure tantalum is available in bar and sheet form and, as such, has been fabricated using standard fabrication methods at room temperature. The metal does not show a transition from brittle to ductile fracture at a temperature as low as − 319 F even at high strain rates. The very low transition temperature of tantalum compared to molybdenum and tungsten is attributed to the higher solubility of oxygen in tantalum which results in a lower tendency for oxides to precipitate at the boundaries.

Since tantalum has high ductility, low transition temperature, and low rate of strain hardening, it can be easily worked and formed at room temperatures into complex shapes. The material is readily weldable by the tungsten inert gas process with local inert gas protection. If annealing is necessary, it should be done at a temperature of 2000–2500 F in a vacuum or in extremely pure helium or argon.

Tantalum has been used successfully in chemical processing equipment. Its corrosion properties can be summarized as follows:

1. Generally inert to acidic solution with the exception of hydrofluoric acid and SO_3 ions.
2. Two or three parts per million of Fl^- ion corrode and embrittle tantalum; however, tests have shown that when chromium is present the fluoride doesn't attack tantalum.
3. Tantalum is attacked by concentrated alkaline solutions at room temperature.
4. Tantalum readily absorbs atomic hydrogen at room temperature and molecular hydrogen above 480 F to form tantalum hydride which results in hardening and embrittlement of the metal.
5. Tantalum is resistant to most liquid metals and is not affected by sodium, potassium, lithium, lead (1832 F), bismuth (1650 F), mercury (1100 F), zinc (932 F), gallium (840 F), and magnesium (2100 F). Aluminum in the liquid state reacts rapidly with tantalum to form aluminum tantalide.

TUNGSTEN

The high melting temperature, useable strength at extreme temperatures, high modulus of elasticity, and promise of high-strength alloys make tungsten a very attractive base metal for extreme temperature applications. Its commercially pure version is available in sheet, bar, and forgings, and it is beginning to see use in several rocket applications. However, its shortcoming of brittle behavior at the lower temperatures and the difficulties associated with fabricating it will require considerable development before it can match molybdenum in actual applications. This, of course, does not include rocket nozzle inserts where tungsten forgings are being used today. It is the tungsten-alloy structural assemblies that are still in the future.

The forming of tungsten sheet is accomplished at higher temperatures than for similar forming of molybdenum shapes. An initial impact forming of tungsten sheet indicates that complex shapes can be formed using this technique. Temperatures 300–500 F above those used to impact form molybdenum alloys should be used. Tungsten cups have been spun by heating the material to several hundred degrees higher than the 1000–1200 F that is required to manually spin molybdenum. For less severe forming operations such as brake-forming and the rolling of cylinders and cones, a temperature of 600–800 F is necessary, whereas only 200–400 F is required for forming molybdenum. However, additional development work on the various tungsten forming processes will be necessary to establish:

1. The optimum working temperatures.
2. The amount of metal that can be displaced per intermediate break-down step.
3. The optimum stress relieving cycles.

The tungsten inert gas process can be used to produce weldments in tungsten sheet. The techniques developed for welding molybdenum have been applied to fusion welding sintered commercially-pure tungsten sheet. Initial studies have shown that the problems for welding tungsten are the same ones that were initially faced with molybdenum, that is, cracking, porosity, and inconsistent penetration. However, a number of sound welds have been produced with automatic welding equipment.

As with molybdenum, the welds in today's material are ductile only at elevated temperatures. The elevated temperature ductility of sheet tungsten fusion welds has been proven by forming them at an elevated temperature after welding. However, much more development work will be required to obtain the optimum conditions of the many welding variables before sound, reliable, and reproducible weldments are possible.

To keep up with the use of sheet metal tungsten components, mechanical fastener programs are proceeding at a satisfactory pace. One-eighth inch diameter flush head rivets have been successfully produced by hot-heading. Tungsten sample joints have been riveted together by heating the rivet and adjacent sheet metal structure prior to upsetting. In all cases, the procedures developed for molybdenum fabrication were utilized for the fabrication of the tungsten assemblies. However, a higher fabrication temperature is required for driving tungsten rivets than is required for driving molybdenum rivets. To date no known attempt has been made to develop tungsten bolts, screws, and nuts. The tendency to chase threads in tungsten is the primary deterrent to producing threaded mechanical fasteners.

The machining of tungsten is difficult and most turning and boring operations are done by grinding. Water-cooled silicon-carbide wheels of 100 to 120 mesh used at speeds of 10–15 sfpm are recommended. Drilling has to be done by the electrical discharge method. To date, carbide and high-speed steel cutting tools generally have proved inadequate in the machining of tungsten. However, carbide cutting tools have been used to bore forged tungsten rocket nozzles. To make the machining of tungsten more practical a new cutting tool technology will have to be developed.

Reliability

Is Built into Transaxles

▶ **The Corvair transaxle uses as many parts and designs as possible from existing production to insure reliability.**

RELIABILITY has been built into the transaxle used on the Corvair by using proved parts or scaled-down performance knowledge whenever possible. This has also resulted in tooling and production savings.

The automatic transmission part of the transaxle was scaled down from the Powerglide so the prediction of its performance was excellent. In addition to drawing on this design experience, the new transmission has wider margins of safety. Some of these are:

- A 40% reduction in gear stress, even though the converter has a 2.4/1 ratio instead of the 2.2/1 used in the Powerglide.
- 50 ft-lb less energy absorbed per square inch of clutch facing during a WOT upshift.
- Shafts at 28–32 Rockwell C are stressed to 38,000 psi at stall.
- Negligible loads on thrust washer and bushings.

Fortunately, there was a six-year pool of experience in aircooled Powerglide designs to draw upon. Although the designs were never put in production, the Corvair had the benefit of this experience.

Another key to reliability is that prototype units were built by production people with production equipment, even to the die cast case of the transmission. One result of this approach is the fact that several Corvair transmissions completed 15,000 miles of the rugged 7 and 11% hill schedule at the Proving Grounds without failure. The normal test requirement of the Powerglide unit is consistently to complete 5000 miles.

The new transaxle differential also draws upon known performance in the selection of materials. This includes the use of cast iron for the carrier, pearlitic malleable for the case, and hardened steel for the other components. Although aluminum was considered for the carrier in early designs, cast iron was selected for its compatible thermal expansion rate with the steel pinion shaft and the iron differential case. This had the benefit of using only two bearings on each shaft without loss of preload or adjustment.

Another example of improved reliability coupled with better performance is the use of a clutch instead of a band to produce reverse motion. Reverse is accomplished, as in the regular Powerglide, by holding the ring gear of the Ravigneaux planetary gear system. In the transaxle, the reaction torque is taken to the transmission case through the six active faces of a plate clutch. Elimination of the reverse band used on the Powerglide and the large radial load it imposes on the planetary has improved gear life. Reverse efficiency is increased approximately 10% due to the absence of this radial force.

To Order Paper No. 140C . . .
. . . on which this article is based, turn to page 6.

This article is based on a paper by K. H. Hansen, R. P. Benzinger, and F. J. Winchell, Chevrolet Motor Division, GMC entitled, "The Chevrolet Corvair."

The paper covers the origin and development of the car, its engine, and its transaxle.

Other articles on the Corvair transaxle appeared in the January and February issues of the SAE Journal.

the M151

a NEW

¼-ton military utility tactical truck

Based on paper by

A. A. Parquette and R. E. Kraemer

Ford Motor Co.

THE M151 — a new ¼-ton military utility tactical truck — is the first completely engineered military vehicle.

Design began with a blank sheet of paper and to meet such significant requirements as minimum weight and maximum performance, every part was subjected to a complete stress and performance analysis. In addition, to satisfy the Army Ordnance "family of vehicles" concept, consideration had to be given to subsequent creation of ¾- and 1-ton vehicles using as many M151 components as possible.

Body frame

The body and frame of the M151 are integral, all steel, and of spot-welded construction. To accommodate the load factor of 5 *g*'s and a target weight of 340 lb, it was necessary to make a complete stress analysis of the body structure. Prior to this, rough design layouts locating all primary members had to be completed, and certain rules were established to assure optimum results.

Some of the rules were:

1. Minimize the number of structural members and joints to eliminate stress concentrations and joint failures.

2. Design all members with a minimum amount of draw and maximum corner radii to avoid wrinkles.

3. Because of the vulnerability of upper sheet metal, body design must permit operation of the vehicle even though a fender were torn off or crushed. Thus, the primary load would be carried by the underbody rails and crossmembers. The upper sheet metal, fenders, side and rear panels would be of

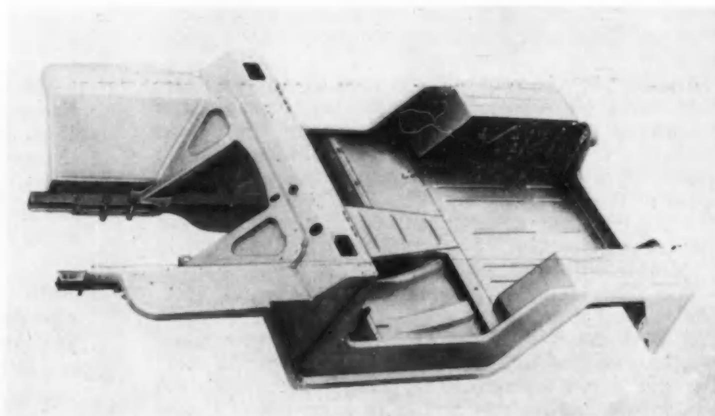


Fig. 1 — Body and frame of the M151 are integral. Underbody has seven structural members. Two channel-shaped main rails with channel filler run from front bumper to rear sill. Two hat-shaped outer rails run from front wheelhouse to rear sill.

M151 Performance

- **Carrying capacity: driver and three passengers, or 800 lb of cargo cross-country, or 1200 lb on highway. Tow 1500 lb cross-country, 2000 lb on highway, when fully loaded.**
- **Start without aid at − 25 F ambient temperature, at − 65 F with heater, and operate at 115 F ambient without auxiliary cooling.**
- **Ford hard-bottom crossings in 20 in. of water; operate submerged in 5 ft of water with snorkels.**
- **Climb hard-surfaced 60-deg grade fully loaded. Maximum drawbar pull 2100 lb with 1200-lb payload.**

minimum gage and strength and function primarily to close in the body.

4. Spot welding would be used throughout the body.

A significant consideration was that should it be necessary to reduce the weight of the vehicle even further, the parameters would permit each body part to be made of aluminum, using the same design parts and metal thickness. The feasibility of this concept was proved later when steel and aluminum bodies of identical design and metal thickness were built and tested side by side.

The body design is shown in Fig. 1. The underbody structure has only seven structural members. Two main rails of channel shape with a channel filler run from the front bumper to the rear sill, passing directly over the rear suspension mounting points and the rear-axle mounting. The pull from the pintle or the front towing and lifting eyes passes directly into these rails as an axial force. Two hat-shaped outer rails run from the front wheel house to the rear sill, passing directly under the driver and codriver positions and over the rear spring seat. Pull from the rear towing eyes and the bumperette impact force carry directly into these rails.

Front suspension

The front suspension package is shown in Fig. 2. It can be removed as an assembly consisting of the front suspension crossmember, suspension arms, pivot bars, springs, shock absorbers, spindles, wheels, tires, brakes, axle and wheel drive shaft assemblies. The spring is positioned just forward of the wheel centerline to provide space behind it for the wheel driveshaft. Under normal load the spring is set at a 14-deg angle with the vertical in the front view and normal to the side rails in the side view.

The lower pivot bar has been raised as high as possible to reduce the possibility of contact of the pivot and the arm with the ground when the suspension is in full jounce. This is mandatory for an independent suspension on a military vehicle.

Rear suspension

The rear suspension is a swung-arm type with arms fabricated from channel sections joined by a spring seat stamping (Fig. 3). Forgings welded into the inner ends of the arms carry the rubber bushings for mounting to the body. The outer end forgings attach to the spindle support casting.

A double-acting, hydraulic shock absorber is mounted behind the rear leg of each arm and incorporates a hydraulic cutoff for rebound control. A very slight trailing arm effect is present since the pivot centerlines of the arms are not parallel with the vehicle centerline in the plan view. Another characteristic of the suspension is its wheel camber change from normal load ride height to full jounce or full rebound. It has not had any adverse effect on tire wear or stability in vehicle tests.

Powerplant

The powerplant package includes the radiator, engine and accessories, clutch, and transmission and

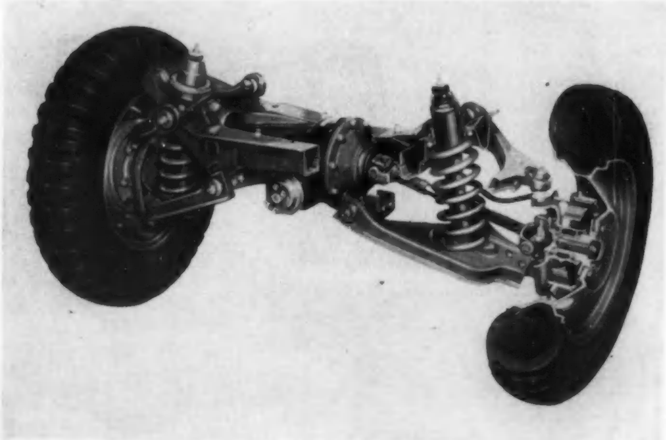


Fig. 2 — Front suspension system is a conventional short and long arm type with coil spring seated in the lower arm and at the top of the crossmember.

Fig. 3 — Swung-arm-type rear suspension of the M151. A variable rate coil spring forward of the wheel drive shaft is mounted between the arm spring seat and the body.

the M151

. . . continued

transfer case assembly. Its total weight is 556 lb wet. The entire package is removed by attaching a sling to two lifting eyes, one at each end of the top surface of the engine, and after removing the brush guard, lifting the engine forward and upward from the front of the vehicle. Package removal makes it possible to service the engine in cold weather regions without draining the radiator and perhaps consequent loss of antifreeze.

Engine

A 4-cyl, ohv, water-cooled engine of conventional cast-iron construction powers the M151 (Fig. 4). Cast iron was chosen rather than aluminum because of its known durability and reliability.

A seamless, stainless-steel, tubular exhaust manifold, saddled on the cylinder head without gaskets, replaces the conventional cast-iron type. This feature offers the advantages of high corrosion resistance, maximum weight saving, and reliability through simplicity. The main oil gallery, usually obtained by adding metal in the cylinder block only to drill it out again, departs from the orthodox. After intensive evaluations of many oil systems, it was decided to "rifle-drill" the camshaft to serve as the gallery. A light-weight camshaft was designed which compares favorably in rigidity and durability with the best commercial cams.

Weight was saved by extensive use of aluminum for engine components. Such items as the intake manifold, front cover, rocker arm shaft supports, water outlet connection, camshaft timing gear, oil pump, oil filter adapter, and carburetor were designed to be cast of aluminum. The total weight of the engine as it evolved closely approached that for a projected aluminum counterpart, and the 3.52 weight/horsepower ratio compares most favorably with the Army Ordnance average of 4 lb per hp for spark-ignition engines.

Many of the latest engine design concepts are employed. The crankcase has a deep skirt extending below the crankshaft centerline to give rigidity (Fig. 5). The heavy-duty, autothermic pistons have a top compression ring with chrome facing, a phosphate-

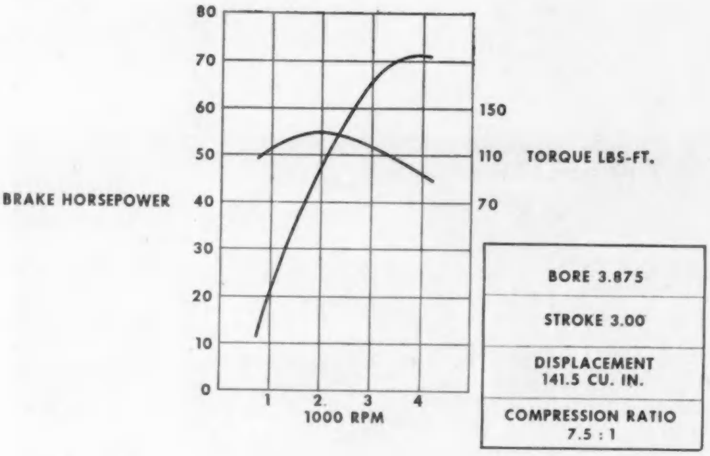


Fig. 4 — Performance curves of the 4-cyl, ohv, water-cooled engine powering the M151 ¼ ton truck. The engine has a lb/hp ratio of 3.52.

coated second compression ring, and two chromed oil rings controlled by a spring steel expander. The forged steel exhaust valves are coated with diffused aluminum after machining. This provides a valve with a desirable grain structure and a coating which covers the metal pores for resistance to pitting and carbon buildup.

Transmission and transfer case

The transmission is a conventional 4-speed, 3-shaft, manual shift type, synchronized in second, third, and fourth gears. A single-speed transfer case is placed behind the transmission and enclosed in the same cast-iron housing. Weight of the entire assembly is 147 lb.

The transfer case consists of three helical gears in constant mesh. The input gear is splined directly to the tail of the transmission main shaft. The idler gear is mounted on the idler shaft using a double row of roller bearings. The output gear is splined to the rear output shaft mounted on two ball bearings.

A sliding spool splined to the front output shaft contains internal teeth which engage mating teeth cut on the end of the rear output shaft when the spool is moved to the rear. This action engages the front wheel drive. A lever mounted at the side of the transmission actuates a shift rail mounted in the housing adjacent to the front output shaft, and movement of the rail spring loads a fork which engages the spool. The shift is not completed on movement of the shift lever until the teeth of the spool are properly indexed with the mating teeth of the rear output shaft. The spring load forces the spool into engagement when teeth are indexed. Thus, engagement of the front wheels can be made while the vehicle is in motion without clashing the teeth.

Originally, a low helix angle was used for the transfer gears, but the result was a high-pitched, intolerable scream. This was overcome by increasing the helix angle to 33.5 deg, resulting in a much higher thrust force from the gears which had to be accommodated. Size and spacing of the transfer idler gear rollers were increased to absorb the increased couple from the idler gear.

Under test, the design of the transmission input gear pocket bearing and the cluster shaft bearings

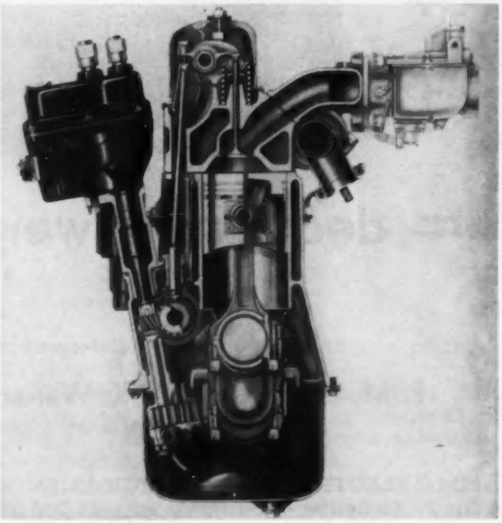


Fig. 5 — Front view of engine showing the deep-skirt crankcase and tubular exhaust manifold of stainless steel saddled to cylinder head without gaskets.

appeared to be inadequate. Accordingly, a test was made to see if adequate lubrication was reaching the bearings. A tracer was applied to one selected bearing and the gearbox was run for a specified time at a chosen speed. The amount of tracer in the lube was measured, changes were made to oil passages, and the test rerun. This procedure was repeated for each questionable bearing until the lubricant showed a minimum content of tracer. From this test it was decided to add oil slingers to the cluster input gear, a most effective device to get lubricant into the input gear pocket bearing.

The M151 is the first Army Ordnance wheeled vehicle produced initially from Ordnance production drawings. The drawing package also includes the arctic, winterization, deep water fording, and hard top kits. Similarly, the program included the preparation of spare parts and packaging requirements, as well as complete technical publications.

To Order Paper No. 125A . . .
. . . on which this article is based, turn to page 6.

8 electrical systems

+

4 generators

+

1 drive

= decrease in weight, space, and electrical

Based on paper by

P. M. Corbett and A. K. Walter

Convair Div., General Dynamics Corp.

MULTIPLE ELECTRIC POWER REQUIREMENTS of the F-106 fighter-interceptor are satisfied by a system using four generators, one constant speed drive, and eight electrical systems. All four generators have similar mounting, driving, and cooling provisions. Major advantages of this multioutput approach are reduced weight, less space, and gains resulting from electrical isolation.

Basic design

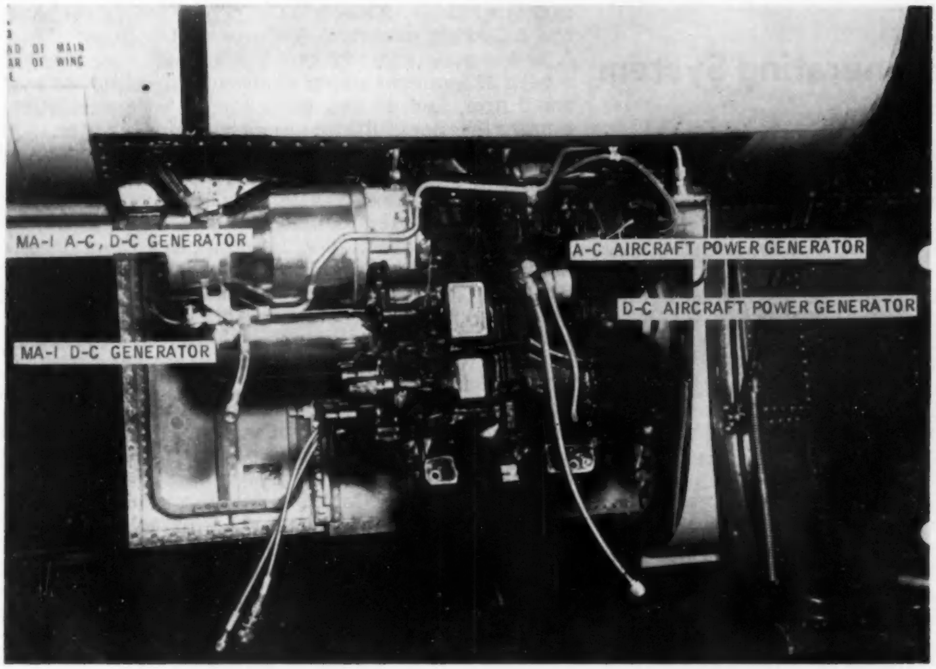
Two triple-output generators supply power for the weapons system (MA-1), and two additional generators are for general purpose aircraft use. In order to obtain the lightest weight system, the stator and rotor are cooled with oil. Rotor cooling oil inlet and outlet design was simplified by employing a gear drive for the generator in place of the usual spline drive.

The multioutput approach was considered best to supply the distinct power forms needed. Consider the advantages of using eight separate generators:

- No inverters or transformer-rectifiers are required for power conversion. This reduces weight, space, and electrical complexity.
- Transient loads resulting in transient voltages are isolated electrically to one source and do not affect the performance of utilization equipment connected to the remaining sources. The speed transient resulting from the transient load is still present, however, since all generators are connected to a common prime mover.
- Adverse electrical characteristics can be avoided more easily by use of separate generators. Certain electronic equipment is particularly susceptible to harmonic content, harmonic distortion, and ripple voltage. It is only at the expense of weight — in the form of filters, generous electromagnetic design, and modifications to related components — that system compatibility can be obtained in single power source systems.
- Overload requirements for the drive can be reduced by utilizing the natural diversity factor existing when separate generators are used. In the case of the F-106 this permitted reducing the usual 150% and 200% overload requirement of the drive to 119% and 145% respectively, resulting in less drive weight.

There are some disadvantages to using separate generators:

- Mechanical complexity and a resulting loss in reliability is introduced by more rotating parts, gears, and bearings. (On the F-106 this is partly offset by using two multioutput machines, each containing three generators.)
- Basic design errors or incompatibilities which may be common to all of the generators are troublesome and costly to correct.
- Ground support equipment must be specially



F-106 constant speed drive main gearbox and generators in swung-down position.

complexity of F-106 power generating system.

designed to meet the requirements of one aircraft. Further, the external power plug must be special to handle each separate circuit.

- Division of cooling oil to each generator under all conditions of manufacturing tolerance and oil temperatures presents difficulties in oil flow matching.

For the MA-1 system, it was found practical to group the high-voltage, low-amperage, d-c generators into one package weighing approximately 30 lb. The a-c generators and the low-voltage, high-amperage d-c generator were also grouped into a single package weighing about 70 lb.

Useable size limitation required that the aircraft power a-c and d-c generators be packaged separately. The d-c machine weighs about 40 lb; the a-c machine about 48 lb.

Characteristics

Mechanical similarities between all four generators include:

(1) Speed — 12000 rpm, except the aircraft d-c

Weapons system electrical requirements are exacting

THE exacting electrical requirements demanded by an integrated aircraft guidance and weapons control system (MA-1) set the standards for the quality of electric power supplied by the constant speed generator drive system.

Basic mission of the F-106/MA-1 weapons system is to intercept and destroy high-speed enemy aircraft. Success of the mission is made possible by a coordinated system consisting of the airplane plus detection, guidance, and armament installations.

Flight mode may be either completely controlled by ground detection and guidance stations or automatically by the airplane's own detection, computer, and navigation systems. Pilot may assume manual control any time at his discretion. Flight time may vary from a few minutes to four hours.

Electric power required totals 41.5 kw continuous (28 kw for the airplane, 13.5 kw for the MA-1 system), 49 kw for 2 min overload, and 60 kw for 5 sec.

The MA-1 system requires that steady state average frequency be maintained at 400 ± 2 cps (± 0.5%). For the most part, the aircraft system utilization equipment is required to operate with a frequency of 400 ± 20%. However, for certain equipment, advantage was taken of the 400 ± 2 cps if it was required to operate from only the nonessential bus.

F-106 Power Generating System

. . . continued . . .

machine which is 8000 rpm.

(2) Drive end bearing — lubricated by oil mist in the gearbox.

(3) Anti-drive end bearing — permanent grease lubrication.

(4) Drive gear. Gear installed on generator stub shaft projects into gearbox approximately 2.5 in. Gear is 30-tooth, 12-pitch spur, except the aircraft d-c generator gear which is 36-tooth.

(5) Cooling oil. Individual generator flow requirement varies from 0.7 gpm to 3.6 gpm at maximum continuous inlet temperature of 275 F (300 F for 10 min) and full electrical load. A parallel cooling oil circuit is used. Flow is from cooling pump to motor to transmission charge pump.

(6) Oil seal. A rotating seal prevents the oil mist in the gearbox (pressurized above 22,000 ft) from entering generator field coil and brush areas. On the MA-1 machines, air is fed to this area at pressure of 1 psi minimum above gearbox pressure. Air pressure prevents oil from passing the seal area. Limited air quantity available required development of a high-temperature potting compound to seal terminal blocks, end covers, and all faying surfaces of the generators. The aircraft power generators have a slinger cavity to collect oil leakage which is then conducted overboard. These machines need no air.

Generator features and ratings

Aircraft generators (Fig. 1) are built and supplied (as Government Furnished Aircraft Equipment) by General Electric Co. These machines have the following electrical features and ratings:

1. A-c generator: 22 kva, 3 phase, 400 cps, 120/208 v with 25 kva continuous overload capability, 33 kva for 2 min, and 44 kva for 5 sec. Static excitation eliminates commutator and rotating exciter. A small permanent magnet generator (PMG) mounts on the shaft drive end to make the generator independent of the d-c system. Efficiency is 80% including the exciter regulator and control panel.
2. D-c generator: 30 v, 100 amp, brushless design using the homopolar inductor generator principle. Six static rectifiers, oil cooled and contained within the generator, rectify the 3 phase, 800 cps low voltage output of the inductor generator. Overloads of 150% for 2 min and 200% for 5 sec are provided without use of a battery operating in parallel. Efficiency is 70% including the control panel. A small shaft mounted PMG provides generator excitation and protective functions and allows operation independent of the battery.

Multiple output MA-1 generators are built and supplied (to Hughes Aircraft Co.) by Jack and Heintz, Inc. These machines have the following ratings and efficiencies:

1. D-c generator: +300 v, 3.5 amp
+150 v, 6.2 amp
−140 v, 4.0 amp
Efficiency is 70% including regulator

2. A-c/d-c generator: 1600 cps, 7.5 kva, 120 v a-c
400 cps, 3 kva 120/208 v a-c
30 v d-c, 60 amp
Efficiency is 70% including regulator

To Order Paper No. 128A . . .
. . . on which this article is based, turn to page 6.

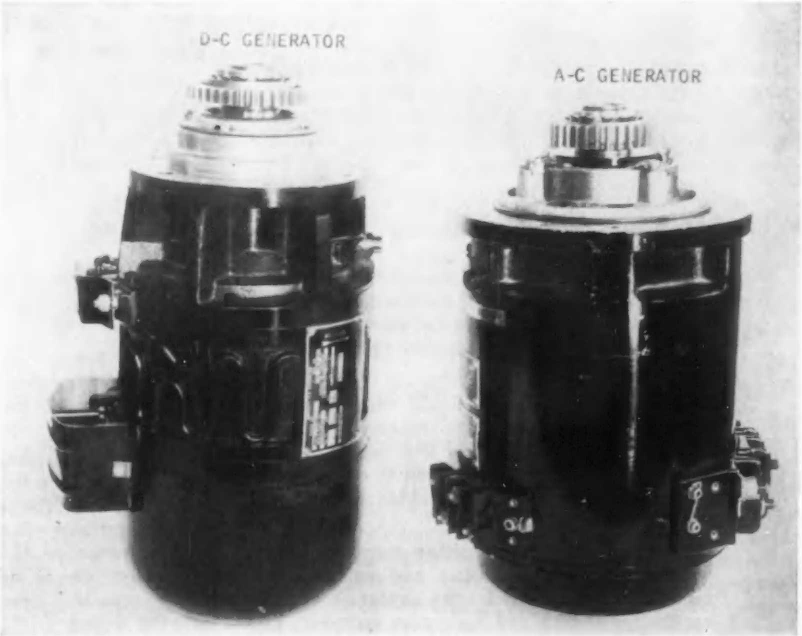


Fig. 1 — Generators for F-106 aircraft power.

Numerical tape control operates 3-stage machine

• Said to be the first automotive production machine to have numerical tape control, it bores, chamfers, drills, countersinks, and taps automatically.

Based on paper by

C. J. Karrer

Detroit Diesel Engine Division of GMC

FEATURING numerical tape control is a three-station machine designed to rough and finish bore, and chamfer the starter pilot hole and to drill, countersink, and tap three holes for starter mounting bolts in flywheel housings. The unit machines flywheel housings for 13 of the 15 engine models built by Detroit Diesel. The housings for these 13 models are currently built in 168 different versions or part numbers with 19 different starter hole positions locating the starter on both the right and left hand side of the engines.

Fig. 1 outlines a housing for an in-line series 71 engine. Note that the starter hole can be located on any one of six different radii to coincide with six possible ring gear diameters, and that its vertical position relative to the crankshaft varies with the desired location of the starter. Besides these two variables of location along the x and y axis, at any given location the hole configuration, which determines the radial position of the starter in its pilot hole, rotates about the centerline of the starter itself. All of these variables are equally applicable to both left- and right-hand parts. The parts vary in thickness from 3½–8¼ in.

These are the variables that faced the production engineer when the decision was made to purchase new equipment for these operations. The usual desirable characteristics of minimum expenditure, minimum operator fatigue, maximum operator safety, and fast changeover from one part to another completed the challenge to the production engineer and the machine tool industry who were to provide the necessary equipment.

The machine that was finally adopted is shown in Fig. 2. It is a three-station machine with standard columns, slide units, and slide unit controls. Beneath the three tool heads is a point-to-point, tape-controlled positioning table with 72×30 in. of travel that carries the bridge-type fixture.

The zero reference point of the tape controlled table can be established and adjusted anywhere inside of the machine. The table is driven by a two-speed motor through a two-speed worm drive transmission and a recirculating ball nut on both the x and y axis. The table always approaches its point of rest from the same direction and always at 0.3 in. per min after stepping down through four speed ranges from a rapid traverse rate of 160 in. per min.

Parts are rolled off the main conveyor onto the elevator (Fig. 3) in front of the fixture. A turn of the air valve raises the elevator to fixture loading height which changes with the thickness of the part being run. The part is slid into the fixture and clamped up against the fixture bridge. The cycle start button is pushed and the tape control takes the workpiece to the first head where boring takes place. At the completion of the boring cycle, the table automatically moves to the second work station where the bolt holes are drilled. When the drill head retracts, the table moves again and the lead screw tap head performs the final operation on the housing

Abridgment of an

SAE Detroit Section Paper

Numerical tape control operates 3-stage machine

. . . continued

before the positioning table returns to the start position.

The radial location of the spindles which countersink, drill, and tap the starter mounting bolt holes is obtained by radially adjusting the three protractor type heads shown in Fig. 4. To relocate a head, the cam lock handle at the right of the head is released, the head manually rotated to its new radial position, and the cam retightened. The change time for any head shouldn't exceed 3 min.

A complete part changeover would also necessitate changing the 1-in. wide, 8-column tape in the tape reader. The tape reader (Fig. 5) is located on a ball bearing mounted shelf in the side of the control console. Changing the tape takes less than 2 min. Since the cycle is repetitive, as batches of 10–500 parts are run at one time, a loop type tape is used to direct the machine. The cycle of the machine is such that the tape shown in Fig. 5 actually contains enough information for three machine cycles.

Tape preparation, a potential stumbling block to the acceptance of a tape controlled machine, has

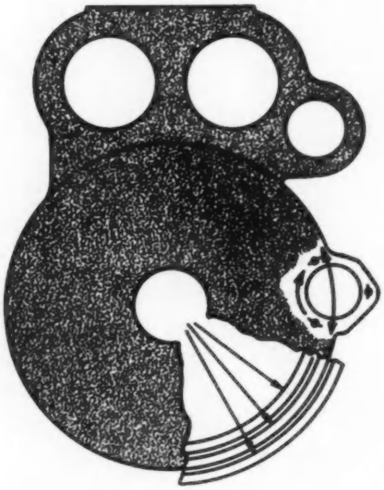
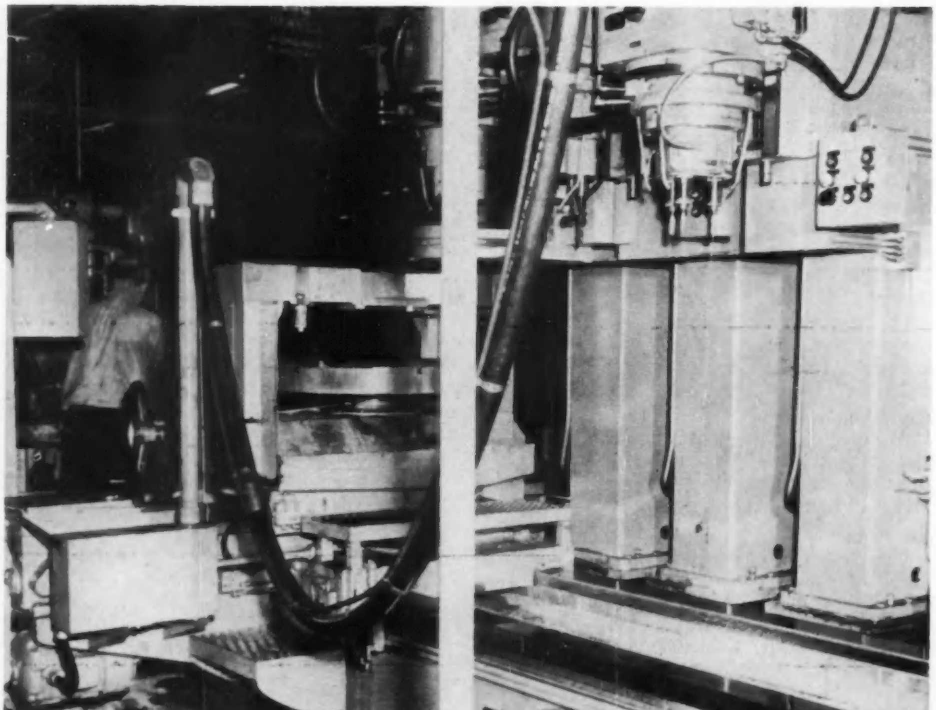


Fig. 1

STARTER HOLE FOR SERIES 71 ENGINE can be located on any of six different radii to coincide with six possible ring gear diameters. The vertical position of the starter hole relative to the crankshaft centerline varies with the desired location of the starter in the vehicle.

Fig. 2

THREE-STATION NUMERICALLY CONTROLLED MACHINE designed to rough and finish bore and chamfer the starter pilot hole, and to drill, countersink, and tap three holes for starter mounting bolts in the flywheel housing.



been simplified by the machine tool manufacturer. Only three x and y coordinates are required. The y coordinate is constant at all three stations and can be read directly from the blueprint. To obtain the x coordinate at station one, the process engineer only has to solve for the third side of a right triangle when one side and the hypotenuse are known. The x coordinate at station two is 24 in. more than at station one and at station three it is 48 in. more.

In addition to the automatic machine cycle, it is also possible to operate the table in a semiautomatic cycle. Here the desired position on the x and y axis is dialed into the console. When this is done and the positioning button is pressed, the table moves to the desired position. When a new position is desired these operations are repeated.

Complete manual operation of the positioning table and all three machine heads also is possible.

This machine demonstrates how ingenuity can simplify an otherwise complex job of tooling. In the simplicity of the machine lies its strength; it is safe and easy to operate, easy to set up, and it can be made to machine a newly designed part in less than one hour, including tape preparation and changeover. It is an example of the application of advanced technology to a current production problem.

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. . . on which this article is based, trun to page 6.

Fig. 3
ELEVATOR AND FIXTURE of numerically controlled machine.

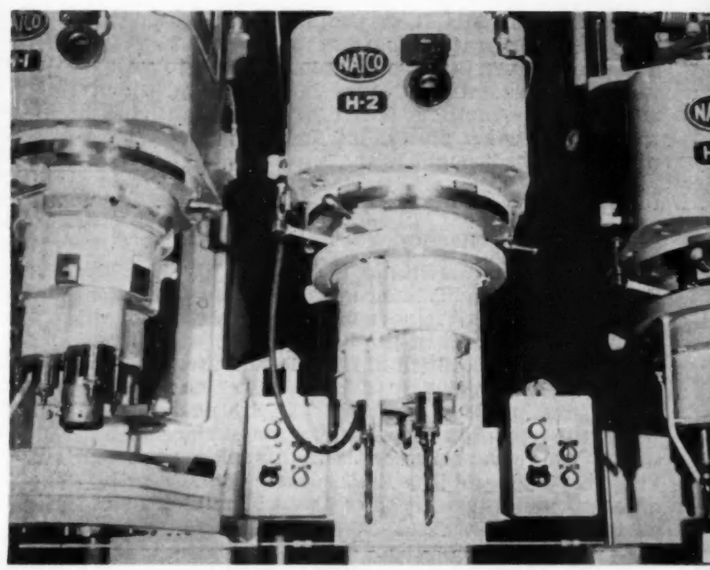

Fig. 4
PROTRACTOR TYPE DRILL HEADS of numerically controlled machine.

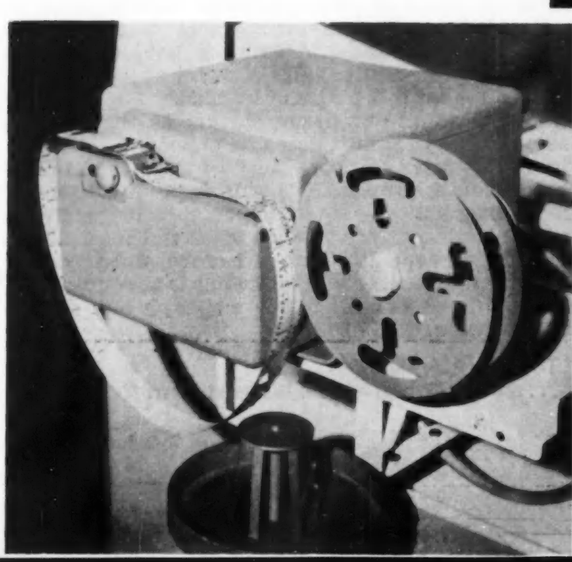

Fig. 5
TAPE READER for numerical control unit.

New Methods of

▶ Electron beam, plasma jet, and high-velocity

to break barriers and

Based on paper by

M. Eugene Merchant

Cincinnati Milling Machine Co.

ELECTRO-CHEMICAL machining has improved the rate of penetration fourfold in the past 10 years and may do even better in the next 10. But to maintain the exponential advance in machining, which won't be easy, methods only now emerging, such as the electron beam, plasma jet, and high velocity liquid jet may be brought to the fore.

Electron beam machining

Electron beam machining is shown in Fig. 1. The device uses a highly concentrated beam of high-energy electrons to remove metal by vaporization at the point of impact of the beam on the workpiece. One typical embodiment of this method uses a beam which can be varied in diameter over the range 0.005–0.030 in. It is claimed that, by pulsing the beam, the temperature gradient at the surface of the metal, where vaporization is taking place, can be kept very high and thus limit surface damage in the adjacent metal to a depth of about 50 millionths of an inch.

At a power level of about 100 kw, this beam is said to be able to slice a slot through ⅛ in. thick stock at speeds up to 60 in. per min, and cut slots 0.001–0.040 in. wide with an accuracy on the width of ± 0.0001 in. The device can be used to trepan and also to contour cavities, the latter at a claimed accuracy in depth of ± 50 millionths of an inch.

Perhaps the most important feature claimed for this method is its virtual independence of the properties and nature of the work material. It works almost equally effectively on materials of extremely high strength as it does on mild steel. While it may not offer the possibility of high rates of metal removal, it can apparently do very intricate and accurate machining on metals of almost any strength level. It could be the forerunner of specialized devices for the intricate precision machining associated with aero-space vehicle manufacture.

Plasma jet method

Plasma jet machining (shown schematically in Fig. 2) is based on the principle of constricting an electric arc (a cloud of ions and electrons) into a slender beam so that its temperature is raised to extremely high values.

The arc is constricted by two processes. First, the arc is surrounded by a cool liquid or gas which, because it cools the outer regions of the arc, reducing their conductivity, forces the current to flow in ever higher concentrations through the center of the arc. When the current in this region has reached high values, a second constriction comes into play. This is the principle of attraction of parallel conductors in which current is flowing in the same direction. The ions, flowing in parallel paths through the constricted arc beam, act like parallel conductors and tend to attract each other, thus further constricting the beam.

Temperatures of 15,000–30,000 F are found in the highly concentrated jet of ions which emerges from the chamber. When such a jet strikes even the most refractory metals it vaporizes them almost instantly. It can knife through a metal plate in short order and, according to reports, leaves a much cleaner edge than possible with ordinary flame cutting.

High-velocity liquid jet method

The idea of using high-velocity liquid jets to machine metal bases on the knowledge that raindrop impact will erode the metal surfaces of aircraft. More recently, Bowden and Brunton have demonstrated that firing 0.01 cc slugs of water at speeds of up to 3500 fps against plates of high strength stainless steel will form pits in the surface by the combined processes of plastic flow and erosion.

Fig. 3 illustrates the possibility of applying such behavior to machining. If the principle of vaporblast is extended to this technique, abrasive might also be introduced into the jet after it leaves the orifice, further expediting the rate of metal removal. Only time and research will tell if this is a technique that can be used as basis for developing a new machining process for 1970.

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Stock Removal

liquid jet may be processes

play roles by 1970.

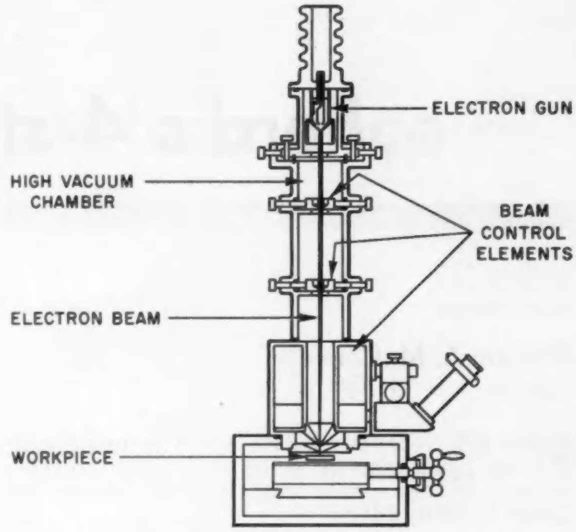


Fig. 1 — Electron beam device promises a means for doing highly intricate and accurate work on metals of any strength, rather than increasing the rates of metal removal.

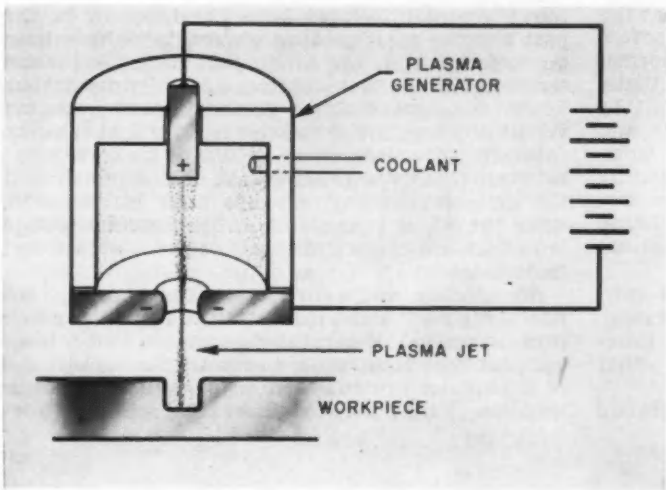
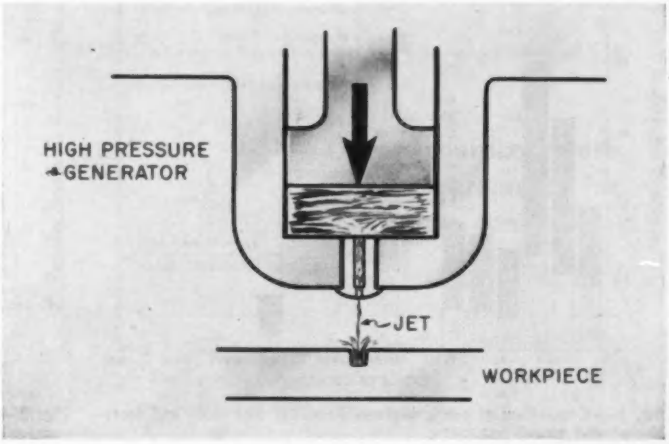


Fig. 2 — Plasma jet machining operates on the principle of vaporizing the metal with a jet of ions at temperatures of 15,000-30,000 F. It is claimed to leave a cleaner cut than flame cutting.

Fig. 3 — Machining with a high-speed liquid jet is a possibility. Impact of raindrops erodes the metal of high-speed aircraft, so why not high-speed jets of water?



Ford's 4-step test program

Based on paper by

William A. McConnell

Ford Motor Co.

FORD gets vehicle test data which correlate with driver experience by using the 4-step program outlined on the opposite page. This article describes the program in detail.

STEP 1:

Endurance testing — proving ground

For proving ground testing, Ford decided that the vehicle should not be subjected to abnormally severe use, but should receive more-frequent-than-normal application of the most severe conditions actually met in service. If quicker failures are sought by arbitrarily increasing the vehicle loads, speeds, and stresses, non-typical failures are produced. However, if the large number of low-stress cycles arising from milder action is eliminated and a more frequent application of higher stress conditions found in service is achieved, correlation with normal use should not be destroyed.

Accelerating tests result in some critical conditions being missed, notably aging, corrosion, weathering, and soaking influences. These time-dependent factors must be investigated in other ways.

Fig. 1 compares a hypothetical proving ground route we had planned to build, with a public highway course we used for test purposes. The public course included the most severe features available. The proving ground contained the same mix of geometric features as the highway route, but they occurred three times as often in a given mileage. Driving speeds were similar, but more frequent stops resulted in a lower average speed for the proving ground. Measurements were made, on a survey vehicle, of vertical accelerations, suspension bottoming, and the like. The proving ground roads were designed to produce the same level of severity for these disturbances as the public highways, but with three times the concentration.

Comparison of proving ground failures with customer complaints have been handicapped in the past because most proving ground tests have been on experimental, pre-production cars. A limited sample of production vehicles normally are tested, however, to get a direct comparison of customer versus proving ground failures on identical vehicles.

Ideally, of course, there should be no correlation between prototype failures and field complaints if the development engineer has done his job well, since the whole purpose of proving ground testing is to find and correct mistakes before the customer finds them.

Abandoning endurance test operations on the public highway and substituting routes on our new proving ground, it became desirable to test a large sample of production cars to replace the background of experience accumulated on previous production vehicles. This permitted direct comparison of prov-

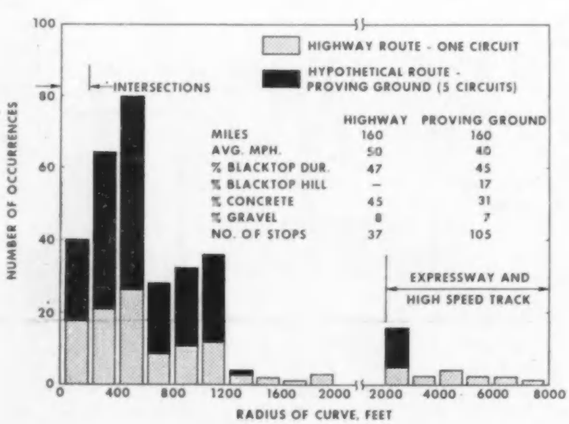


Fig. 1 — Comparison of public highway durability test route and tentative proving ground test route.

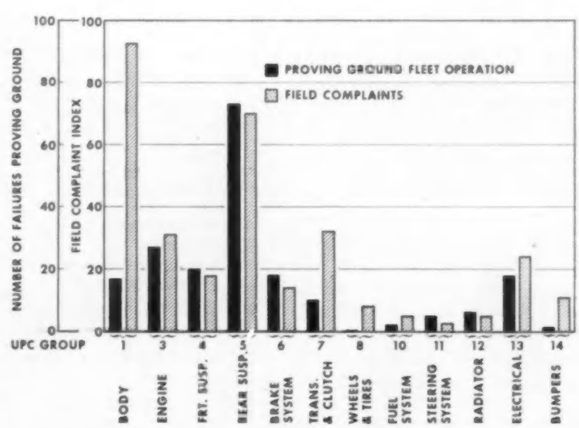


Fig. 2 — Number of failures during proving ground operation versus number of field complaints on similar items.

simulates driver performance

ing ground-to-field experience with a statistically significant fleet of test vehicles from the same model year.

Fig. 2 shows the number of failures by Uniform Parts Classification (UPC) grouping, which occurred on proving ground cars, compared with complaints from the field. In general, where there were customer problems, there were proving ground failures.

Several dozen cars were included in the proving ground sample. However, there were different numbers available for comparisons of production parts in the different UPC groupings. More representative test data would compare the number of failures in each UPC grouping as a per cent of the number of cars involved, as in Fig. 3 even though the exact number of vehicles generating field complaints is uncertain.

Expressed as a per cent, the proportion of proving ground failures is much higher. Note that there is a 20 to 1 ratio (Fig. 3) in the vertical scales. This means that if claims originate from 2% of the cars in the field, we can expect similar difficulties on 40% of the proving ground fleet.

The average mileage accumulated on the proving ground cars included in this comparison was about 30,000 miles. Field complaints were reported only for the 4000-mile warranty period. A better way of viewing the significance of the 20 to 1 ratio of percentages, therefore, is to consider that a vehicle tested for 30,000 miles on the proving ground will generate as many failures as 20 vehicles driven by customers for 4000 miles each.

Expressed in terms of failures per car-mile, which

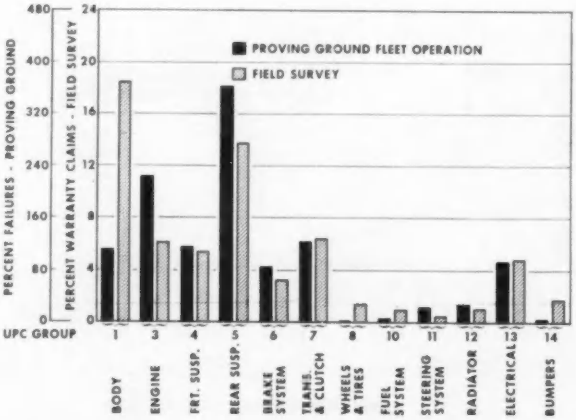


Fig. 3 — Comparison of per cent failures — proving ground operation versus field survey results.

Step 1

Set up proving ground routes to simulate field data.

Step 2

Develop techniques for simulating service life in the laboratory.

Step 3

Select performance measures to match customer needs.

Step 4

Improve and standardize these measurements for better comparisons.

Ford's 4-step test program simulates driver performance

. . . continued

is indicative of the severity of the route, about two and a half times as many failures per car-mile occur on the proving ground as there are warranty claims per car-mile from the customer. This is a lower ratio than might be expected from three times the frequency-of-occurrence of the severest loadings. By way of explanation, we note that the proving ground procedure falls short of producing the expected proportion of failures in the body UPC groupings. Customer complaints in the body area are largely concerned with defective finishes, rusting of ornamental parts, and certain chronic functional disorders that include leaks, shakes, squeaks, and rattles which are normally reported only once on proving ground tests.

If the calculation of relative severity is adjusted to include only the mechanical and structural type of customer failures in the body group, two and one half times as many failures occur on the proving ground as in the hands of the customer.

Test cars have been operated on another route at our Dearborn Proving Ground, known as the Rough Road Durability Route. This route consists of a 10-mile circuit, with a high proportion of Belgian block, cobblestone, rough gravel, and sharp turns.

Comparing rough road route operation with field results, we find little correlation in many areas. This route, for example, does not develop engine and brake failures. However, body, suspension, and steering system defects are magnified (Fig. 4).

Fig. 5 shows this data on a percentage basis to adjust for the different number of cars participating. There is again about a 20 to 1 ratio of per cent failures between certain of the UPC groups and field survey data — but there are no failures at

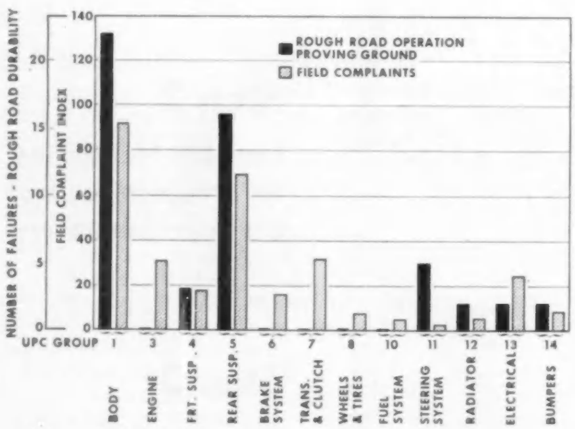


Fig. 4 — Number of failures during rough road operation versus number of field complaints.

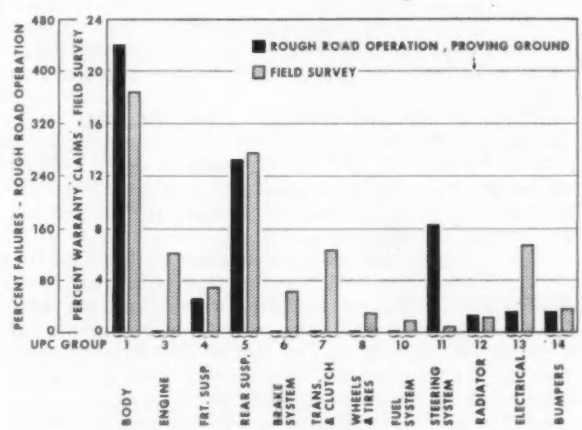


Fig. 5 — Comparison of per cent failures — proving ground rough road operation versus field survey results.

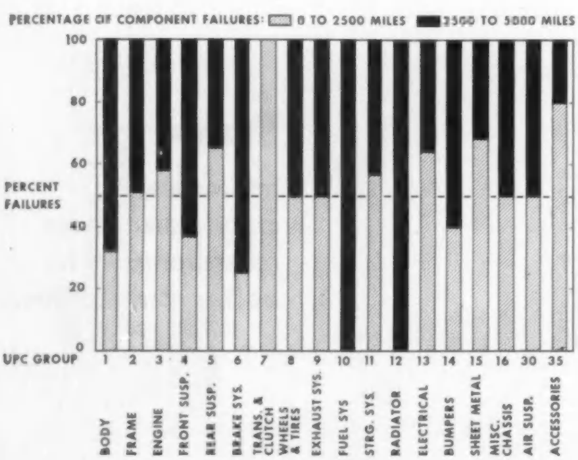


Fig. 7 — Distribution of failures during proving ground rough road operation — 1957 and 1958 production and prototype cars.

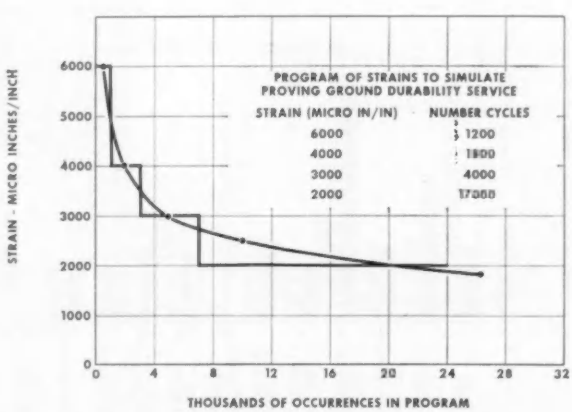


Fig. 8 — Strain versus frequency-of-occurrence on proving ground durability route — typical chassis component.

all in five of the groups. While body failures appear to correlate, the failures observed are not always typical of field complaints, consisting as they do of weld and metal failures where field claims in these areas are relatively low. The same is true in other areas. For example, the high incidence of rear axle housing fractures on the rough road course is disproportionate.

Since the degree of magnification, or the severity ratio of the route, is not the same for different components, we can find no sound basis for relating this abnormally severe operation to customer use. While it is true that 5000 trouble-free miles on the rough roads may assure no trouble on the highway in selected areas, it might also mean that some parts are overdesigned. We suggest that this type operation be used only to check the relative merit of alternate designs, and that adequacy or inadequacy be established by operations more closely approaching normal use.

Figs. 6 and 7 show the distribution of failures with mileage. On proving ground durability tests, about as many failures occur up to 20,000 miles as occur between 20,000 and 40,000 miles. Also, very seldom do failures develop in the last 20,000 miles of a type different than those occurring in the first 20,000 miles. The exceptions are mostly items where age and weathering is a factor. This suggests that there is little value in extending the durability operation beyond 20,000 miles. Fig. 6 indicates that failures are nearly equally distributed throughout the mileage. The same has been true on other durability tests of our own and competitive products, in which accurate maintenance cost records were kept for a 20,000 mile period. The chief virtue of extending mileage is to assure development of typical failures on a limited sample, and thus increase test validity.

On the rough road or cobblestone route, failures are not as uniformly distributed with mileage (Fig. 7), although again, typical failures are evident with few exceptions in 2500 miles.

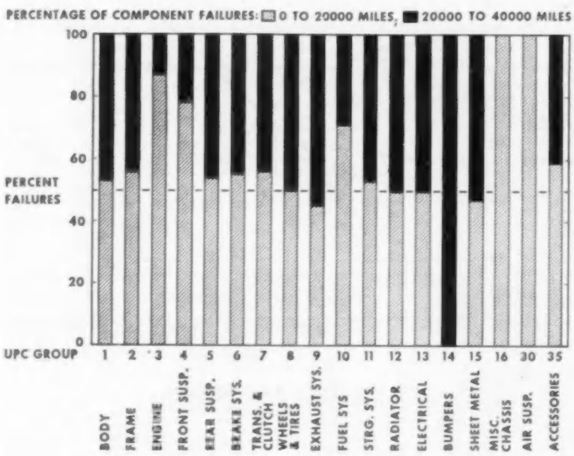


Fig. 6 — Distribution of failures during proving ground durability operation — 1957 and 1958 production and prototype cars.

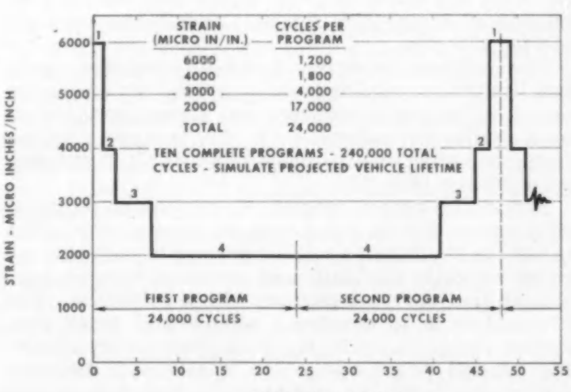


Fig. 9 — Laboratory programming to simulate proving ground durability route — typical chassis component.

STEP 2:

Endurance testing — laboratory

Endurance testing in the lab is approached much the same as road testing. Applied loads must be realistic if failures are to be typical. Accelerated tests are obtained by more frequent application of normal loads, and not by increasing operating severity. The major problem here, as on the proving ground, is in establishing a relationship between service life to the customer and the number and magnitude of the artificial load or duty cycles to be applied. If we know how many times a vehicle component is subjected to the various levels of usage in its expected lifetime, we generally can set up a simulated test in the lab that will give realistic results.

There are many items that are of the on-off or open-shut variety which require only knowledge of "how many times" to set up laboratory tests. Most electrical switches or controls, doors, deck lids, and window and hood operating mechanisms fall into this category. Instrumentation for getting this type of data is relatively straightforward. An electric switch located at the item under observation actuates a counter when the item is operated. It is necessary only to operate the vehicle in normal customer fashion to obtain good operational data. Since many items usually are observed on the same vehicle, each has its own switch and counter.

Unfortunately, most vehicles are subjected to varying degrees of usage. This complicates the instrumentation since it must measure not merely "how many times," but also "how much" does "how many times" occur. One way of getting these data is to use an oscillograph.

To convert an oscillograph record into usable information, traces are analyzed to determine the frequency-of-occurrence of various magnitudes over the entire route. Plots of frequency-of-occurrence information taken from an oscillograph record look like Fig. 8.

Having the frequency-of-occurrence curves, a laboratory test is devised that will duplicate or approximate the curve. If conventional testing machines are used, the frequency-of-occurrence curve is ap-

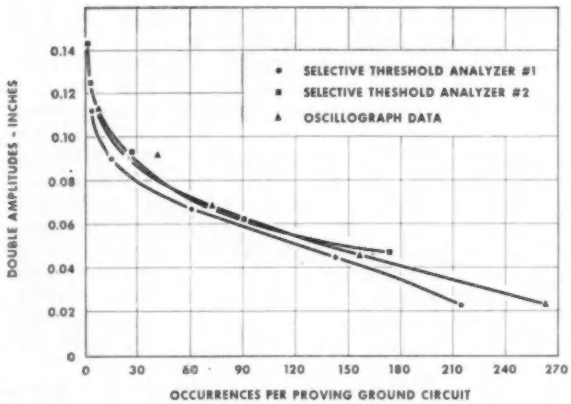


Fig. 10 — Typical vibration characteristic curves — double amplitude versus number of occurrences.

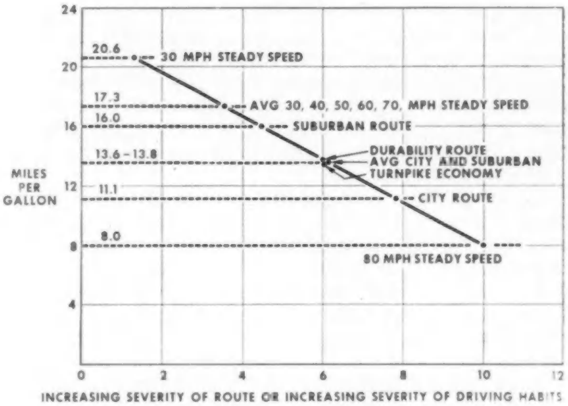


Fig. 11 — Various economy measures of a typical car.

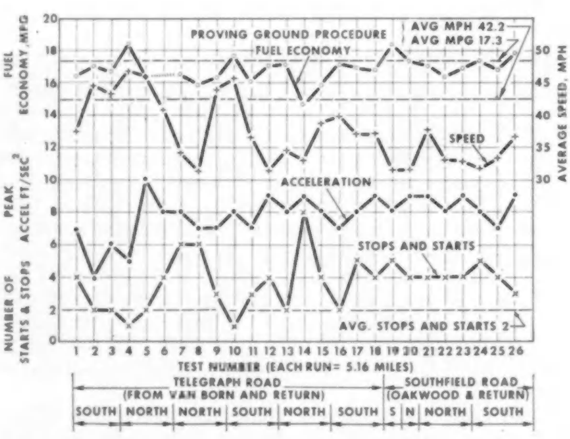


Fig. 13 — Comparison of simulated proving ground suburban economy route and actual highway checks using a typical car.

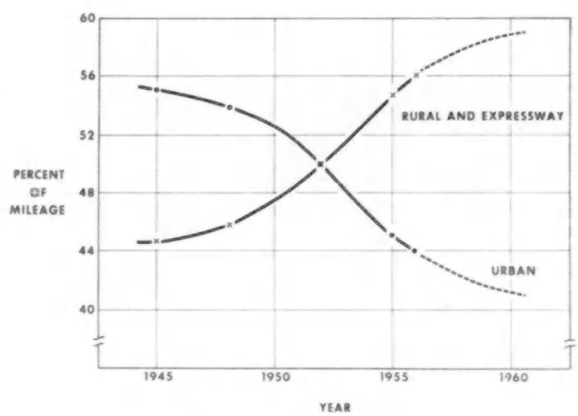


Fig. 14 — Trend in driving habits.

Ford's 4-step test program simulates driver performance

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proximated by using the step function shown in Fig. 8.

Recognizing that the order of application of strain, from low-to-high or high-to-low, has an effect on fatigue life, the random distribution of loading which occurs in actual road operation also must be simulated. Generally, this is done by selecting a program of loading that will be repeated many times during the test, and by running the program in both directions as shown in Fig. 9.

To overcome the problem of analyzing all this data, an Electronic Selective Threshold Analyzer was developed. This instrument consists of several counters that total the number of times the load amplitude exceeds certain preselected values. Upon completion of the road test, the numbers on the counters are recorded from which load versus frequency-of-occurrence fatigue load curves can be plotted directly.

The original selective threshold analyzer (#1) has limitations which make it useful for analyzing only low-frequency occurrences. Development work on a similar instrument (#2), for analyzing higher frequency road strain measurements, is a pressing requirement (Fig. 10).

It does not appear feasible, at present, to establish duty cycles for all categories of components. The influence of changing vehicle designs is such that we cannot specify the loads and cycles to which a particular load-carrying member will be subjected. The alternative is to develop a simple and rapid procedure for establishing the load program on a proving ground check run. The relationship between test cycles in the lab and required customer service life is then found from the 2½ to 1 ratio between proving ground and customer mileage.

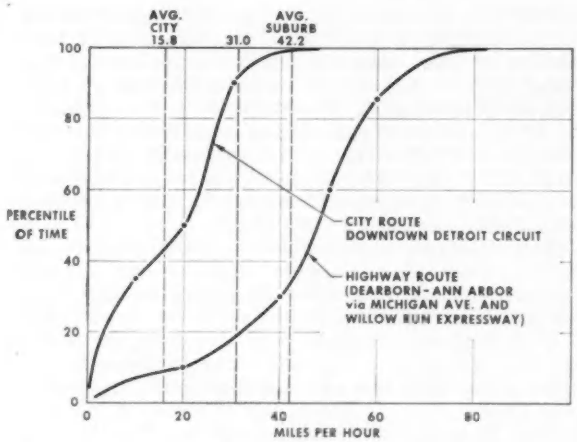

Fig. 12 — Percentile speed distribution — city and suburban routes.

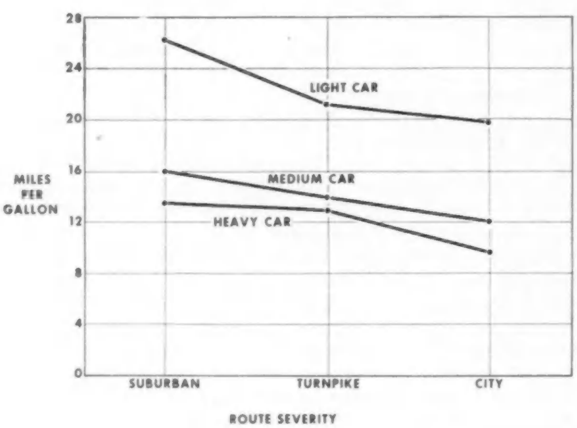

Fig. 15 — Fuel economy comparisons.

STEP 3:

Performance testing

In the area of performance testing, recent effort has been directed toward establishing reproducible measures truly representative of conditions which a large number of customers will experience. Covered here are a few of the parameters which are most familiar, how they relate to actual customer operation, and some of the precautions necessary to assure valid comparisons uncontaminated by extraneous variables.

Fuel economy is a major concern of the customer. In comparing alternative designs, we would prefer to measure one value of "miles per gallon." This number should reflect the economy which could be expected by the majority of customers.

Unfortunately, fuel economy is not a factor, like weight or price, that can be adequately characterized by a single number. No one average value can describe what the majority of customers will get. Reliance on such an oversimplified description can lead to poor product decisons, or conceal areas where further attention is needed.

There are five major influences on economy which can affect results more than differences between vehicles. These include, in approximate order of importance: speed; changes in speed; route; weather; and the driver. Fig. 11 shows fuel economy of a typical car as measured by several different methods. Different test methods can show a 2 to 1 difference in economy on a particular vehicle. Likewise, customer usage can give similar extremes in economy. Two other points should be noted, however. First, for any one of these test conditions, there is only a 1½ to 1 spread between the most economical of current domestic automobiles. Usage can cause more difference in economy than design. Second, it is unusual for any one make of vehicle to surpass its competition under all of the conditions shown. No single figure, or single average of a group of figures, can show correctly the relative merit of two vehicles, unless the average is weighted to represent all types of usage.

For many years the automotive industry used — and still uses — what we call a steady speed economy test. This test, run at various constant speeds with stabilized temperatures, on level roads, eliminates the driver influence and is the most reproducible road test.

Unfortunately, the steady speed test yields results much higher than any customer will get. The effect of weight, vehicle inertia, transmission efficiencies during accelerations, accelerator pumps, and warmup also have been ruled out as variables along with the driver. Consequently, this test is supplemented with actual runs in the city, on the highway, or over proving ground durability routes, which give lower and more realistic economies. These tank economies, however, are highly variable due to traffic and road conditions as well as driver habits. Differences in designs are masked. Comparative tests are run in convoys because evaluations from one day to the next are of little value. As a result, these tests have been set up on the proving ground, where there is no traffic interference, and where rigorous speed-time, stop, and acceleration schedules can be maintained.

Fig. 12 shows a plot of speed distributions on a public highway course that has been used for customer-type economy checks in downtown Detroit and from Dearborn to Ann Arbor. This route, together with information on starts, stops, and acceleration levels reached, formed the basis for the city and suburban economy procedures we now use. While considerable departure from these curves occur with daily traffic variations, we feel they are typical of traffic patterns in and around large cities.

Note that use of an average city-suburban route with an overall average speed of 31 mph would suit neither city nor suburban drivers. Ninety per cent of the time city drivers would not reach the average speed, and over 80% of the time suburban drivers would exceed it. The percentage of time drivers operate at or around the average speed is small.

Fig. 13 compares the results of a series of suburban economy runs over several five-mile local stretches of road with the suburban portion of the simulated proving ground route (dotted line) Note that the patterns of starts, stops, accelerations, speeds, and fuel economy on an actual highway run

Ford's 4-step test program simulates driver performance

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vary widely. These 26 checks were made on a single car, over a period of two days, and do not reflect total traffic variations. Obviously, if any comparative testing is to be done, it must be done on private roads with full control of the driving program. It is also apparent that the economy obtained on such a proving ground simulated route is close to that obtained on the Southfield and Telegraph checks, as well as on the Expressway and Michigan Avenue checks which it was designed to reproduce.

In establishing the city and suburban routes on the proving ground, a total length of 8.8 miles was chosen. This is about the median length of trip for the country as a whole. The trend in driving habits has shifted in the past few years (Fig. 14), to where the largest part of car mileage is accumulated on rural roads, and expressways — about 60% at present. Our proving ground city and suburban test route was laid out with 60% of the mileage (5.2 miles) on a suburban schedule, to match current customer usage. Thus, the average of the city and suburban economies obtained should be a properly weighted average.

However, a satisfactory average could be achieved from a low suburban and a high city economy, with consequent dissatisfaction for most customers. Only if automobiles are acceptable in both areas are we pleasing most owners.

In recent years, there has been a trend to higher speed on rural roads and expressways. With many controlled access superhighways already in use, and with funds committed for an interstate highway system similar to the present toll turnpikes, to be developed over the next ten years, this type of operation will increase.

There are many highway studies which show that speeds in the 70 mph region are normal to turnpike operation, and that speeds on these roads are remarkably steady. While the actual mileage accumulated at speeds of 70 mph and above is still low — only about one billion miles annually at present — this is expected to increase appreciably — perhaps to 30 billion miles by 1963. These fast miles will be accumulated mostly on longer trips, where the customer is especially sensitive to his gasoline economy. Consequently, we feel that the city and suburban economy data should be supplemented by a higher speed economy figure — a turnpike economy value — which we feel is satisfactorily simulated by the 70 mph steady speed economy obtained on the proving ground. Fig. 15 shows what these three economy parameters would look like. The heavy car is relatively better, the light car relatively worse in turnpike type operation.

Methods of measuring and presenting vehicle acceleration performance data have undergone similar evolution in the past two years. Previously, data were obtained to show acceleration rate as a function of vehicle speed. While this had some engineering value, such acceleration curves were not convenient for evaluating comparative performance. Measurements of speed as a function of time were also made; but again, the relative performance of two vehicles was not readily apparent. Consequently, distance travelled from a standing start — in 4 sec, and in 10 sec — have come to be accepted criteria of "getaways." This approach places cars in their correct relative position, as the customer would see it if he were to engage in a sprint from a stop light.

These two measures give only one view of acceleration as the customer uses it. Passing performance is another vital requirement, and a car with excellent startup can be very sluggish in passing at highway speeds. The measure we use to evaluate passing ability is the danger time, or time required to gain certain standard distances over a steady speed car. These exposure times are presented for several initial speeds, usually 30, 40, and 50 mph. Since most people estimate clearances in feet rather than in seconds, the total distance travelled while completing a passing maneuver is also used as a criterion.

There are two common performance measurements which relate directly to highway situations. One of these is grade climbing ability, which we can determine precisely by tractive effort, or drawbar, measurements on level roads. The force applied to a car by a towing dynamometer is directly analogous to the downhill component of the weight of a vehicle operating on a grade. Tire, wind, and various mechanical efficiencies are identical in the two situations. Thus a drawbar effort versus speed curve with the ordinate expressed in per cent of vehicle weight instead of pounds pull indicates directly the limit of grade capability at each speed, or the maximum speed possible on each grade.

Simulating grade effect by the application of controlled drawbar loads has been useful in developing engine cooling procedures for passenger cars. Full throttle cooling tests on cars are unrealistic with current power-to-weight ratios, automatic transmissions, and improved highways. There are no highway features which require full throttle for more than a few seconds, and the heat capacity of the system will accommodate these transient peak thermal inputs. Our present test procedure for cooling assumes that the continuous heat input is limited to that resulting from negotiating certain standard highway gradients. Minimum highway standards allow 10%, 8%, and 6% grades for design speeds of 30, 45, and 60 mph, respectively. These grades and speeds, together with 75 mph on level roads, are considered representative operating conditions where stabilized temperatures might be reached. There are such grades in the vicinity of our Arizona proving ground, and our experience has been that cars which operate satisfactorily in the 100–110 F ambients common in these areas are satisfactory elsewhere.

In comparing data from these performance tests and especially in correlating projected vehicle performance with subsequent road tests, it is necessary to consider the effects of the weather.

The two main weather influences on performance test results are ambient temperature and barometric pressure. These influences affect the vehicle in two ways; they produce variations in wind and running friction, or power required to move the

vehicle; and they produce variations in engine breathing capacity, or maximum power output.

There are established methods for evaluating temperature and weather effects on both power requirement of the vehicle and power output of the engine, under steady speed conditions.

Examination of the results of hundreds of road load-power requirement tests at a variety of temperature and pressure conditions show that the vehicle resistance is inversely proportional to absolute temperature, and proportional in part to atmospheric pressure. All of the wind, tire, bearing, and rolling losses appear to be effected in the same way by temperature; only the wind resistance is affected by the air pressure. The following equation is used to adjust test data:

Power required, standard conditions =

$$\frac{\text{mph}}{375}\left[F_{\text{Rolling}} + F_{\text{Air}}\left(\frac{\text{bar. standard}}{\text{bar. observed}}\right)\right] \times \left[\frac{460\ \text{temp. observed}}{460\ \text{temp. standard}}\right]$$

Fig. 16 is a comparison of road power data on a 1958 Ford 6 under widely different temperature and pressure conditions, with both sets of data corrected to a common standard. In this case, the pressure correction is small, and only about one-fourth as great as that due to temperature.

Tests have also been run on the road using driveshaft torquemeters, and results compared with engine dynamometer checks of the same engine. Use of the standard SAE correction formulas have satisfactorily reconciled dynamometer and road test data. Fig. 17 shows a typical horsepower curve.

Application of power correction formulas to road performance tests is complicated by two factors. Normally, engine power is not measured on acceleration tests, and the relative effect of weather on both power requirement and power developed varies continuously throughout a test run as a function of vehicle speed. Nevertheless, a method has been found to apply weather corrections which is theoretically sound and accurate.

Briefly, the technique involves running through a calculation of the particular performance parameter to be corrected, using known vehicle characteristics and observed test weather conditions. The same calculation is then repeated, changing only the weather conditions, to the desired standard. Comparison of the two calculations yields a difference which is applied to the test result as an additive correction. Since vehicles of the same performance level are affected to about the same extent, it has been possible to develop correction tables for each performance criterion for various temperatures and pressures.

At present, fuel economy correction techniques need refinement. While the major result appears to be the effect on road load power requirement, there are significant secondary effects of temperature, pressure, and humidity on carburetion and air/fuel ratios.

We have not yet found a sound theoretical basis for correcting engine cooling data to a standard condition. When tests are conducted to determine the ambient temperature required to produce boiling, obviously the engine power output and heat rejection should be adjusted to whatever the value would actually be at this air-to-boil temperature.

If cooling tests are run at some lower temperature, the engine output will be higher, and the calculated air-to-boil figure will be too low. During wind tunnel tests we have found an empirical relationship which says that for every increase of one horsepower in engine output, there will be a decrease of one degree in the air-to-boil figure. This relationship appears to hold approximately for all the part throttle loads used on passenger cars, and for full throttle tests as well, and is a useful relationship in evaluating road cooling tests, and reconciling differences between cooling tests run under different weather conditions.

STEP 4:

Accuracy of test data

Even with corrections or allowances for weather variations, there are limitations to test data which must be recognized, especially when comparing different makes or types of vehicles. Automobiles —

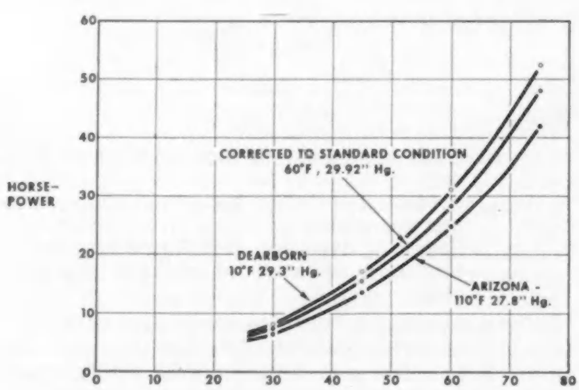


Fig. 16 — Variation of road power requirements with ambient conditions — 1958 Ford 6.

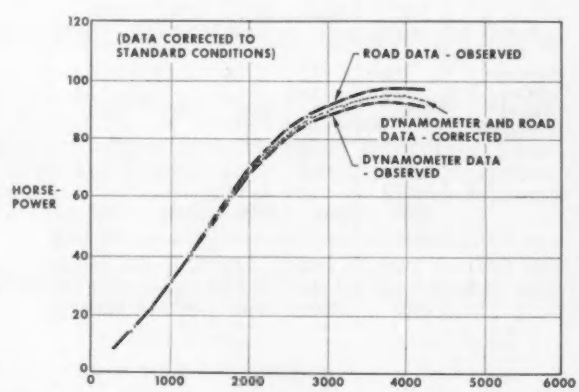


Fig. 17 — Comparison of full-throttle horsepower for typical car — 3rd gear.

Ford's 4-step test program simulates driver performance

. . . continued

even those that are nominally identical — are all slightly different. To establish characteristics of the species, it is better to measure them all, or as many as we can, with even a crude caliper, rather than to take one and examine it with the most precise tool. To have confidence in the reliability of our test data, we must consider both the variability between individual samples and the variability of our observations of those samples.

We express accuracy of our test data, therefore, as a per cent range within which there is a certain probability that the true value will be found.

Table 1 shows the accuracy we can expect from one of our performance tests with various numbers of cars in the sample, and with various numbers of observations on each sample, at an 80% confidence level. Thus if we want results that will be accurate to better than 2% four times out of five, we will have to test at least two samples. If we want better than 1% accuracy, we must make five tests on each of five samples. If we want to work with better odds — say 19 times out of 20, or a 95% confidence level — all the accuracy percentages shown will be increased to about 1½ times the values in this particular table.

Cost data (Table 1) help us decide how much accuracy we can afford. Doubling accuracy roughly quadruples cost. It is also apparent that procuring and preparing additional samples is more costly than increasing the number of tests performed. There are other consideration that are sometimes dominant — for example, available manpower or time allotted. Inclusion of all these factors in a table allows us to choose a test program which will give the best results compatible with practical limitations and economic justification.

Accuracies are shown in Table 1 both with and without weather corrections applied. The utility of corrections is perhaps greater than the differences between the figures would suggest. The series of tests from which these accuracies were derived were performed before we had much faith in our correction techniques. Consequently, the data were all accumulated at one proving ground area with a relatively narrow barometric pressure variation, and only on days when ambient temperatures were within a 45–75 deg range. We now feel we can allow substantially more latitude in weather, so that many more days will be suitable for performance testing, and we can be less concerned over the altitude and pressure differences between our three proving ground locations.

The basic information used to develop accuracy tables for each of our vehicle performance parameters (acceleration, passing ability, city and highway fuel economy) was derived from a fleet of 45 cars of our own and competitive makes with up to 12 test observations per car. In most cases, there were three vehicles of each type, and four tests on each of these three vehicles. From these data we could establish a total variation including both sample differences and observational error. From the repeat tests on particular samples, we established variations due to observational error only. The difference between total variation and observational, or test variations, gave a variation due to differences between samples. By using the following formula the car variations and test variations were combined to find a total standard deviation for other combinations of sample size and number of observations.

$$\sigma^2_{\text{Total}} = \frac{\sigma^2_{\text{Car}} + \dfrac{\sigma^2_{\text{Test}}}{N}}{K}$$

Where:

N = Number of tests on each of K number of cars

σ_{Total} = Standard deviation including sample and test variations

σ_{Car} = Standard deviation of multiple samples

σ_{Test} = Standard deviation of multiple observations

It is interesting to note that the variability between different samples of the same type car was surprisingly uniform for all the different makes and performance levels of cars tested.

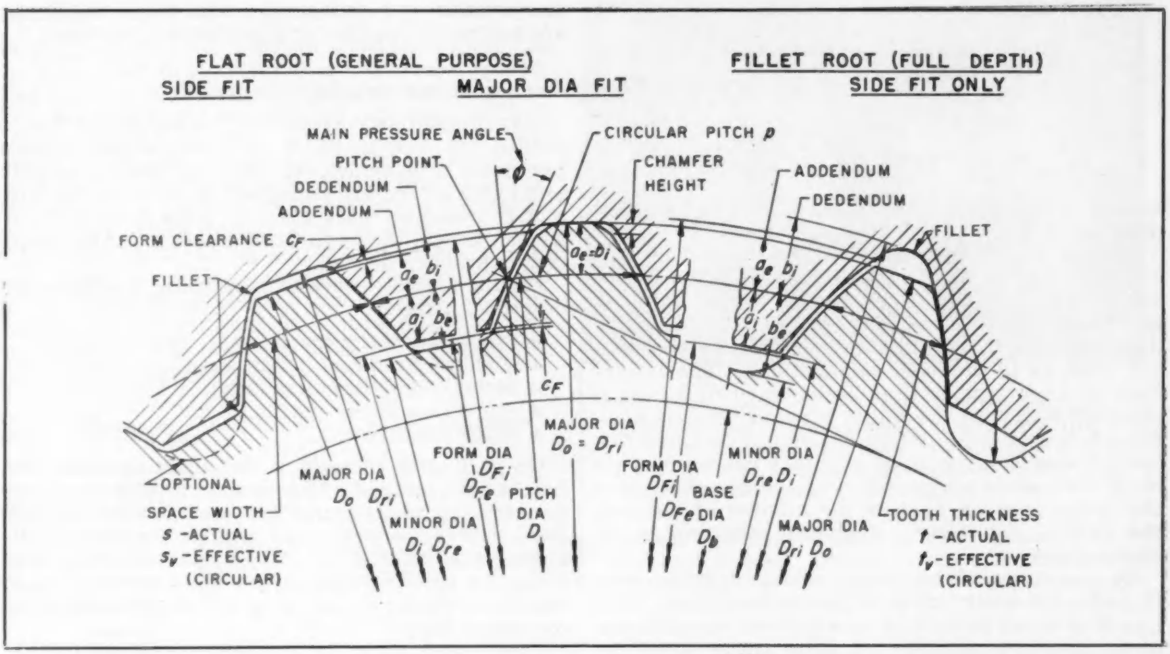
Table 1 — Accuracy of Test Data versus Test Cost for Various Sizes of Sample, Various Numbers of Test per Sample

Top Line: Data Accuracy—Uncorrected
Middle Line: Data Accuracy—Corrected
Bottom Line: Cost of Test

Number of Cars Tested \ Number of Repeat Tests Per Car	1	2	3	4	5	
1	± 3.8% ± 2.7% $1250	3.0 2.3 1400	2.7 2.2 1600	2.5 2.1 1800	2.4 2.1 2000	1
2	2.7 1.9 2450	2.1 1.7 2800	1.9 1.6 3200	1.8 1.5 3550	1.7 1.5 3950	2
3	2.2 1.6 3650	1.8 1.4 4200	1.6 1.3 4800	1.5 1.2 5350	1.4 1.2 5900	3
4	1.9 1.3 4900	1.5 1.2 5600	1.4 1.1 6350	1.3 1.1 7100	1.2 1.1 7850	4
5	1.7 1.2 6100	1.4 1.1 7000	1.3 1.0 7950	1.2 1.0 8850	± 1.1% ± 0.9% $9800	5
	1	2	3	4	5	

Number of Repeat Tests Per Car

To Order Paper No. S210 . . .
. . . on which this article is based, turn to page 6.



First complete

Spline and Serration Standard

bows in with 1960 SAE Handbook

▶ **Completion of the inspection section gives designers, manufacturers, tool vendors, and inspectors one standard they all can use to assure production of interchangeable splines within required fit limits.**

SPLINES that fit every time and that can be produced economically are now an every-day reality, thanks to a 20-year effort which produced the first *really* complete spline standard, appearing in the 1960 SAE Handbook. The final key to this event is the completion of a definitive section on inspection. This allows the designer, manufacturer, tool vendor, and inspector to talk a common and concise engineering language.

Once the designer has calculated the spline size for maximum load, the standard provides all needed specifications, including the accepted method of making spline product drawings. The new inspection section assures the designer that only parts that are strictly within specification limits will be used in final assemblies and that the spline fit will effect the design intent.

The manufacturer and tool vendor can use the standard to get a complete explanation of the specification method and inspection procedure. Thus, errors caused by ambiguous drawings can be avoided, and the most liberal allowances and economical manufacturing method encouraged.

At the same time, the clear presentation of the subject by the standard makes it easy for the designer to apply deviations from the standard in rare cases where this may be needed.

Advances in spline inspection

Two major advances in the new spline inspection section are the comprehensive coverage of analytical inspection of index, profile, parallelism, out of roundness, and eccentricity errors and the introduc-

First complete

Spline and Serration Standard

bows in with 1960 SAE Handbook

. . . continued

tion of sector gages as an extension of paddle plug and snap gages.

Splines with high numbers of teeth used by aircraft propeller manufacturers suggested the use of sector plug and ring gages instead of paddle plugs and tooth thickness snap gages. The sector gage has distinct advantages when splines with many teeth are used, as in propeller applications. The difference in gage type is that sector gage measures a constant 30 deg of the spline whether this arc contains 2 or 20 teeth. When the spline contains few teeth, the sector gage may only have two teeth similar to the paddle plug, but as the number of teeth in the spline goes up, so does the number of teeth in the sector. Fig. 1 gives the tooth relationship for sector gages.

By checking a 30-deg sector at a time, the inspection of a 144-tooth spline is greatly simplified. The loss of detailed knowledge of what each tooth in the sector measures is accepted, since these numerous spline teeth are used not because of the load requirements, but rather, because of fitting a spline to a large diameter.

At the same time that the introduction of sector gages was made, gage information was simplified. This is done by presenting the gage illustrations, the formulas for their essential dimensions, and corresponding references to part dimensions in one place. Before, the standard user had to skip through the 79-page standard to get gage design information. An improved bar chart better explains the relationship of gage dimensions to part space width and tooth thickness specifications. It covers the standard and two alternate systems of dimensioning, thereby establishing the space width and tooth thickness tolerance allocation for all possible types of gages, except two. These two, minimum actual space width and maximum actual tooth thickness, are not recommended for acceptance inspection.

Analytical measurement improved

Now, the different types of spline errors are clearly spelled out and methods for their measurements presented and evaluated. Errors, such as profile and index errors, are important in determining why a manufactured part did not pass inspection by gages. Often, they point out where manufacturing corrections are needed.

Profile Errors — Several measuring methods are described, namely:

- Profile checking machines.
- Dividing head and height gage.
- Series of pin measurements.
- Projection of the profile.
- Master templates.

Of particular interest is the dividing head and height gage method. This method rotates the spline through roll angle increments and the height gage then tells if the surface is where it should be (dimension *AB* in Fig. 2). A new table of roll angles (supplied by the Vinco Corp.) gives the degrees of roll for any diameter, making the height calculation extremely easy.

Total Index Error — The merits of direct inspection with precision indexing devices are described and the influence of eccentricity on the index error is discussed.

Parallelism — Two methods of measurement, (shown in Fig. 3), are introduced. Although the "B" method yields numerical values that are too small, they can be readily corrected by dividing by the cosine of the pressure angle.

Out-of-Roundness — This is treated as the result of spacing and profile errors which already define the spline contour. In cases of thin rings subject to deflection, it is recognized that cut-of-roundness may be the cause of spacing and profile errors.

Eccentricity — Measurement by readings over pins, rolling inspection with master gears, and gages are evaluated. The interrelation between out-of-roundness and eccentricity are clearly distinguished.

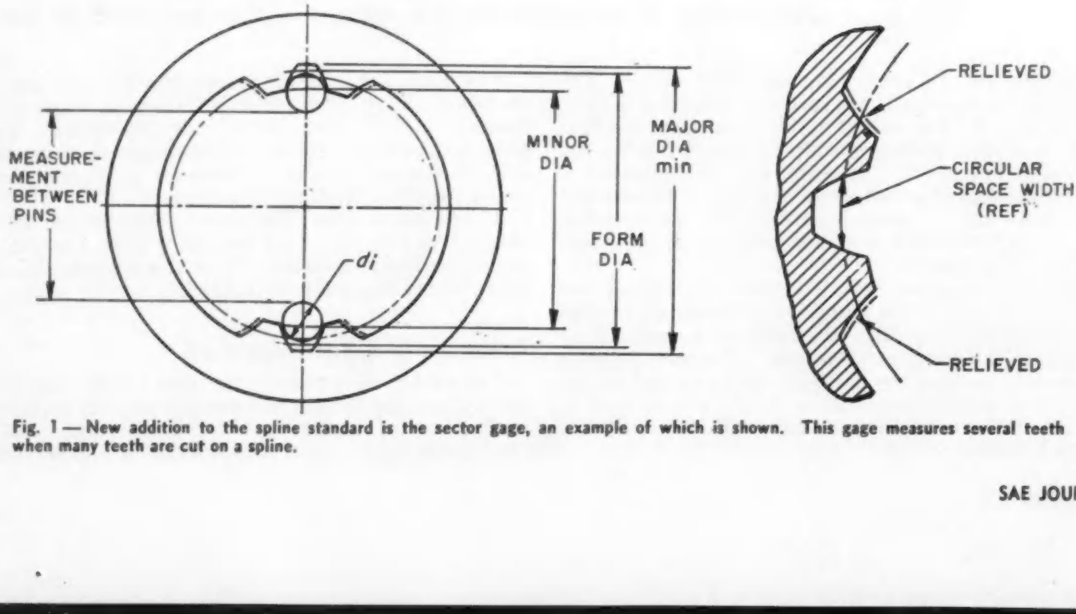


Fig. 1 — New addition to the spline standard is the sector gage, an example of which is shown. This gage measures several teeth when many teeth are cut on a spline.

Improvements in splines

Two changes to the basic standard have improved the manufacturing techniques for some splines. They are the increases of room between the major diameter and form diameter of internal flat root splines and the elimination of nonstandard hobs needed to cut external splines with a smaller number of teeth by modifying the spline form diameter.

Experience with the 1957 Handbook provision showed that there wasn't enough leeway to generate a fillet by a shaper cutter, or to allow for tip breakdown of broach teeth on internal flat root splines. This situation was overcome by dropping the form diameter of internal splines and adjusting the chamfer and outside diameter of external splines. The changes made are:

Type of Spline	Dimension	1957 Handbook	1960 Handbook
Flat root side fit	Major diameter, internal	$\frac{N+1}{P}$	$\frac{N+1}{P}$*
	Form diameter, internal	$\frac{N+1}{P}+2c_F-\frac{0.182}{P}$	$\frac{N+0.8}{P}-0.004+2c_F$
	Major diameter, external	$N+\frac{0.818}{P}$	$\frac{N+0.8}{P}-0.004$
Flat root major dia fit	Major diameter, internal	$\frac{N+1}{P}$	$\frac{N+1}{P}$*
	Form diameter, internal	$\frac{N+1}{P}+2c_F-\frac{0.182}{P}$	$N+\frac{0.8}{P}-0.004+2c_F$
	Major diameter, external	$\frac{N+1}{P}-0.0001$	$\frac{N+1}{P}-0.0001$*
	Chamfer, external		
	min	$\frac{0.131}{P}+0.004$	$\frac{0.14}{P}+0.006$
	max	$\frac{0.091}{P}$	$\frac{0.1}{P}+0.002$

* No change.

THE originator of the "effective" dimensioning concept for involute splines, **A. S. BEAM** (left) is shown discussing this story with the new chairman of the SAE Involute Splines, Serrations, and Inspection Subcommittee, **LEON N. DEVOS.**

Beam was first exposed to spline specification problems 15 years ago when given a Buckingham Manual of Gear Design and asked to design gages for a set of mating involute splined parts. Despite his then limited knowledge of the subject, he soon became aware of the problems of specifications needed to assure proper assembly of splines.

The result was the "effective" dimensioning concept of spline specifications, which he presented to the SAE in a formal paper. The concept was then introduced by DeVos to many industries as a practical means of putting spline production on a controlled basis. This control assured the assembly of splined parts to the design intent.

The vehicle for transforming the "effective" dimensioning concept into a practical tool for industry has been the Involute Splines, Serrations, and Inspection Subcommittee under the chairmanship of George L. McCain. For many years, Messrs. Beam and DeVos have worked with other members of this group to achieve this goal.

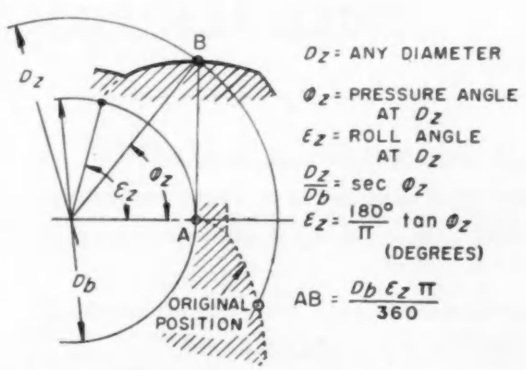


Fig. 2 — New tables on roll angle, ε_z, make the setup calculation for involute profile checking easy.

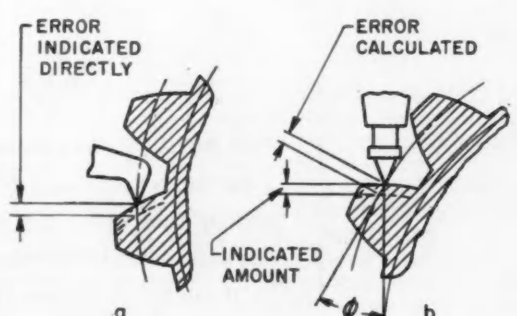
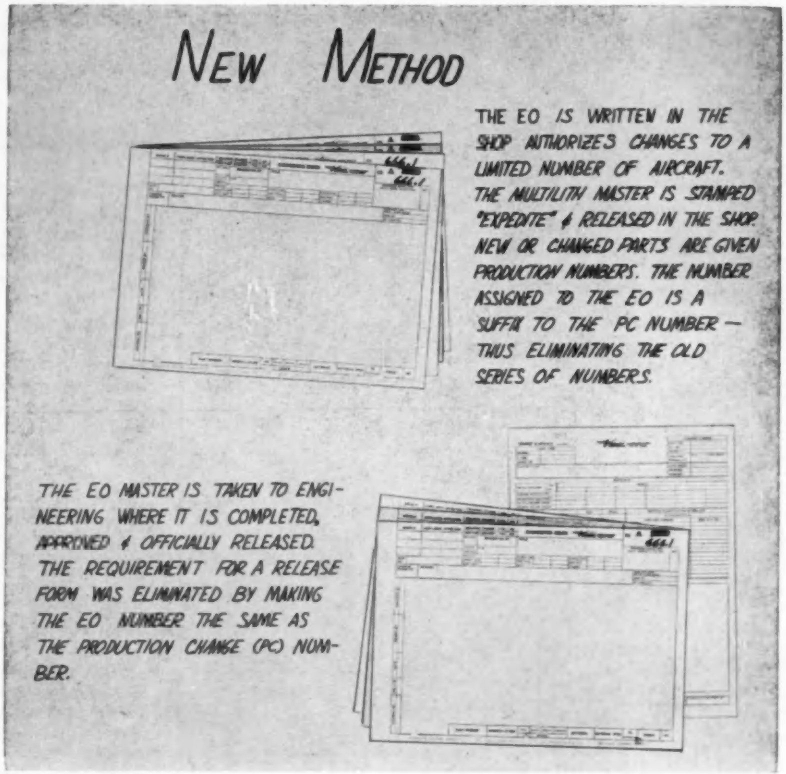


Fig. 3 — Added to the standard are technique for measuring individual spline errors. Two ways of indicating parallelism error are illustrated.



New Method

New method of issuing Engineering Orders instead of Engineering Floor Action Instructions.

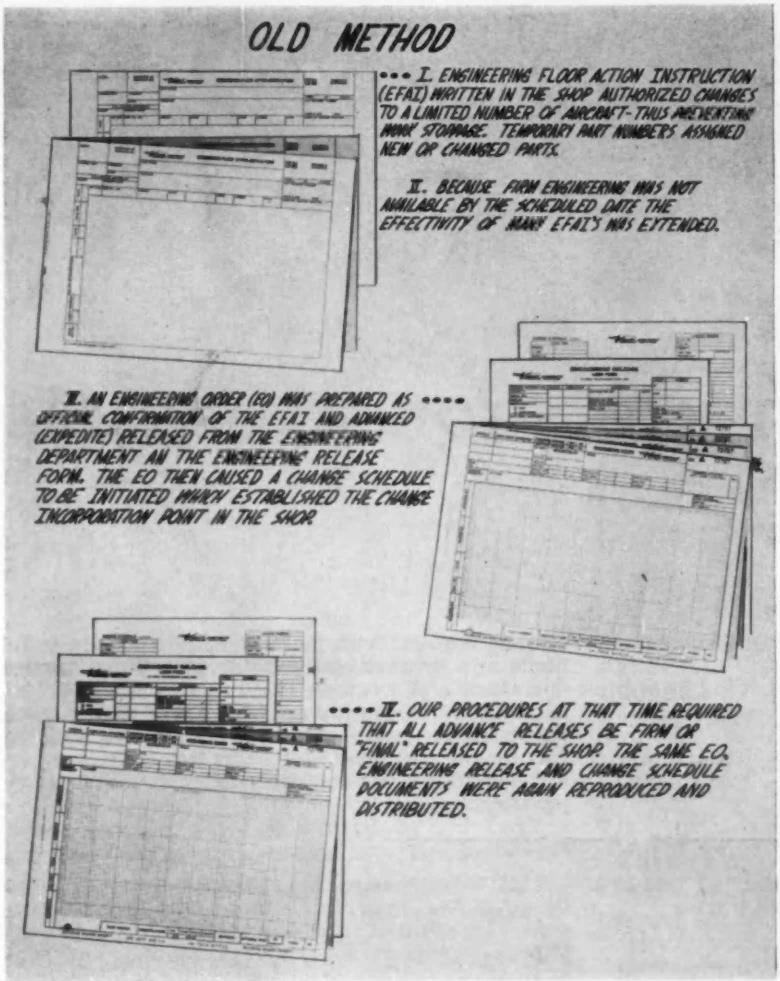
Huge savings possible

Engineering

THIS ARTICLE gives a specific example of how $245,000 a year was saved. . . .

But the potentials in a typical company — where half of its 10,000 employees are creating paper work — are much greater. The annual cost of clerical labor and paper may well run to $13,000,000 per year.

"If only 5% of this amount could be saved by thoughtful simplification," says Author Helstrom, "such a company would realize true savings of $650,000 a year."



Old Method

Old method of issuing and confirming Engineering Floor Action Instructions.

through *simplifying*

Paper Work

Based on paper by

H. A. Helstrom, Jr., Chance Vought Aircraft, Inc.

BY a single change in its engineering paper work, Chance Vought is saving something like $245,000 a year . . . by NOT issuing any more some 100,000-plus sheets of paper per month. The saving comes partly from paper cost; partly from the fact that each of these 110,000 sheets of paper would have had to be handled by several employees and either filed or thrown away. The changed system has now been in satisfactory operation for nearly a year and a half.

The satisfactory, new, cost-saving way of handling Engineering Orders is illustrated and described at the top of page 90 . . . and the old method is illustrated at the top of this page.

Scores of opportunities exist, Chance Vought engineers believe, for major cost reductions through elimination of paper work. Such reductions, they say, are "nothing more than applied good judgment sometimes married to a high-speed computer, which can consider an almost infinite number of alternates instantaneously."

To Order Paper No. 156A . . .
. . . on which this article is based, turn to page 6.

Airlines compromise on towing tractors for heavy jets

Based on paper by

J. C. Laegeler

The Frank G. Hough Co.

TOWING TRACTORS for the Boeing 707, Douglas DC-8, and Convair 880 represent a compromise least objectionable to the airlines. Study of the many specifications desired by the airlines and discussion with airlines' engineering and operations people resulted in the following principal features and characteristics for the composite tractor:

1. Gasoline power
2. Four-wheel drive — (two-wheel drive option)
3. Four-wheel steer — (two-wheel and crab steer option)
4. 30,000 lb static drawbar pull on concrete surfaces
5. Torque converter and power shift transmission
6. Road speeds to 18 mph
7. 10,500 lb drawbar pull at 5 mph and 5500 lb drawbar pull at 10 mph
8. 37.5 kva power unit compartment
9. Maximum height of 60 in. (without cab)
10. Maximum height of 88 in. (with cab)
11. Maximum width of 96 in.
12. Maximum length of 220 in.

These major specifications fairly well define the tractor; so, the design problem was rather specific. The designers were not to determine how best to tow a commercial jet airline, but instead to design a tractor to meet these specifications. The specifications were not arbitrarily selected. All had their roots in some operational problem, as can be seen below.

Gasoline engine

Ground equipment maintenance personnel were already familiar with gasoline engine service technique and generally unfamiliar with diesel service operations. A gasoline tractor engine would also permit the 37.5 kva ground power unit to feed from the same fuel tank, resulting in only one kind of fuel for the combined unit. Gas turbine power also was considered, but its high first cost was felt to be prohibitive.

Four-wheel drive

This feature was almost unanimously requested by all of the domestic airlines. The primary reasons: it permitted all of the tractor weight to contribute something toward drawbar pull, and controllability, while turning and pulling a heavy load, could be at a maximum since roughly equal weight on all four wheels could be achieved without sacrifice of drawbar pull.

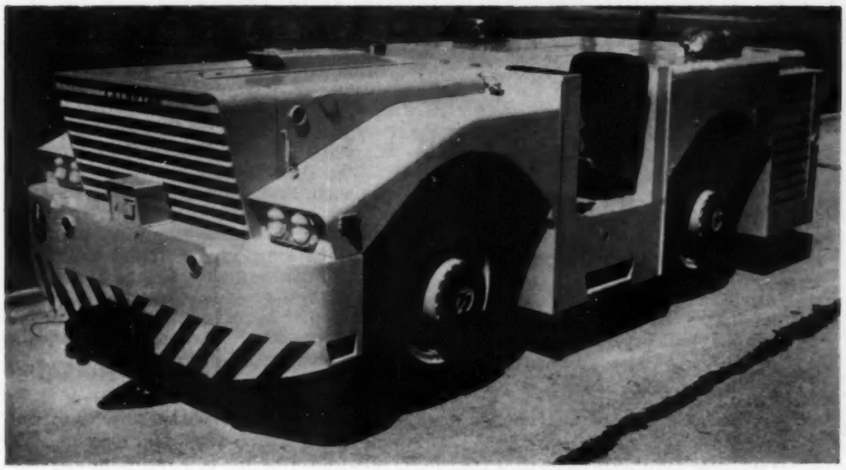
The two-wheel drive option was provided to minimize tire wear under light load or when the tractor was traveling but not towing.

Four-wheel steer

Four-wheel steer was needed to compensate for the limited turning ability of driving steering axles. Optional two-wheel steer was requested by some airlines because they felt that high speeds in open areas with this more conventional type of control would be less apt to confuse operating personnel and thus reduce the likelihood of accidents. Crab steer was requested by several airlines again to offset the limited turning ability of a driving steering axle. It was felt to be helpful in maneuvering the airplane in close quarters.

30,000 lb drawbar pull (static)

This value of static drawbar pull was the maximum requested by the airlines. One airline required less pull, and special arrangements were made to limit the weight of their tractors. Those who asked



for the maximum pull had in mind the need to pull the aircraft from holes or depressions in the ramp paving. The need to push an airplane backward against the thrust of idling engines was also a factor. Depending on conditions, the total thrust developed could be 2,500 lb or more.

This value of static pull directly established the vehicle weight of approximately 40,000 lb. A maximum coefficient of traction of 0.75 was felt to be the highest realistic value attainable.

Torque converter and power shift transmission

Both of these features were almost unanimously requested — the torque converter because of its value in smoothly starting a load and its inherent ability to broaden the operating range of any given gear, and the power shift transmission because of its ability to shift under power, thus allowing the load to be kept moving during a shift under conditions of high rolling resistance.

Road speeds to 18 mph

A maximum road speed of approximately 18 mph was agreed upon as about as fast a speed as anyone would want to tow 5 million dollars worth of airplane.

Dynamic drawbar pull

The dynamic drawbar pull of 10,500 lb at 5 mph and 5500 lb at 10 mph were the most specific and the highest stipulated by any airline. To satisfy these conditions of approximately 147 drawbar horsepower, a 260 hp gasoline engine was required. This relationship of input to output horsepower was not only the result of power losses due to engine trim and drive line inefficiency, but also in part due to the difficulty of matching a standard engine, converter, and transmission to meet the two specified dynamic test points, the static drawbar pull specification, and the travel speed limitations.

37.5 kva power unit

When the airplanes are to be towed more than a few feet, all of the airlines require that a man be stationed in the crew compartment so that the airplane brakes can be applied in an emergency. Operation of these brakes, in turn, requires that the hydraulic system, which is electrically controlled, be functional. In addition to this, it is often desirable to have electrical power available at the instrument panel and for operation of the radios. There has been some disagreement as to how much power is required for these operations, but 37.5 kva has been used by many airlines.

The power unit design was not a part of the tractor program, but still it has to be carried by the tractor in a suitable compartment made as a part of the tractor. These power units are gasoline engine driven and take fuel from the tractor fuel tank. In addition, the power unit engine exhaust system has been provided for in the design of the tractor.

Dimensional limitations

The dimensional limitations were rather arbitrarily selected to be consistent with the general requirements of most airlines. The maximum height limitation was rather severe, and one direct result of it was the selection of a horizontal engine. A vertical engine compatible with the transmissions available could not be found at the time of the original design. Later developments in the transmission field ultimately changed this.

There were actually many other minor design specifications stipulated; however, for the most part these did not individually contribute much to the overall towing concept. They did, however, result in many hours of design work, and they of course ultimately contributed to a fair share of the resulting vehicle cost. The twelve points discussed were by far of overriding importance with respect to the end result.

To Order Paper No. 115B . . .
. . . on which this article is based, turn to page 6.

Briefs of SAE PAPERS

Continued from p. 6

tion methods; complete heat balance is obtained so that actual efficiencies or coefficients of performance can be calculated; numerical examples covering range of operation between adiabatic conditions and isothermal operations.

Optimization of Phase Angle and Volume Ratio for Stirling Engines, T. FINKELSTEIN. Paper No. 118C. Paper refers to closed, reversible regenerative gas cycle machines which operate as prime movers, heat pumps and refrigerators; principles and possible designs; analytical expressions for pressure variations, work output and heat transfer quantities are derived; nondimensional parameters are defined, including group expressing "Specific Performance"; analytical simultaneous optimization for two basic design parameters.

New GMC V-6 and Twin Six Engines, C. V. CROCKETT. Paper No. S228. New family of GMC gasoline engines, covering three V-6's and one Twin Six, is described in detail. Engines range from 150 to 275 hp. Well-illustrated with photos of various parts and graphs showing performance curves.

Product Planning in Automotive Business, R. I. RICE. Paper No. S229. Discusses the job of the product planning department in the development of cars and trucks that are acceptable to the public in terms of cost, styling, durability, reliability, etc. Also touches on evolution of Falcon, small car business in general, high labor costs in America and their effect on car export business, the automobile as a status symbol, and costs of truck ownership.

MATERIALS

Fundamentals of Polymer Progress, H. MARK. Paper No. 119A. Survey on present use of polymers in automobile tires, etc.; how performance of presently used materials could be improved from point of view of producer and ultimate uses of vehicle; probable progress in polymer science and technology is formulated and increased future application of polymers in vehicle industry predicted.

MISCELLANEOUS

Overall Viewpoint of Systems Analysis, M. M. FLOOD. Paper No. 113A. Definition of term which is applied to preliminary design studies of very complex man-machine systems; four main steps are: system concept, feasibility, development monitoring, and evaluation testing; use of techniques is illustrated by example relating to industrial inventory control system design problem; second example makes use of model developed and used by Operations Research Dept., Univ. Michigan, for design and evaluation studies of antiaircraft weapon system.

Strategy, Tactics, Weapons Systems and Men, E. A. JOHNSON. Paper No. 113B. Systems analysis deals primarily with future of system and uncertainty in expectation of particular value of particular technologically dependent system parameter; it is rate of increase of new technical knowledge that provides raw material for systems change; effect of this knowledge on weapons development is shown and illustrated by examples.

Multivariable Experimentation, W. J. YOUDEN. Paper No. 116A. Account of some of statistical design techniques appropriate for complex studies that have been developed in last 15 yr; general approach to experimental objectives such as selection of few variables that could be studied or quantitative effects of variables already selected; technique of fractional factorials; weighing designs; response surface designs.

Terrestrial Tilling in Space Age, H. C. ZEISLOFT. Paper No. 112A. Peaceful uses of results obtained within National Aeronautic and Space Administration Program, are summarized with regard to various fields and applications; development of structural materials such as synthetics, metals, glass adhesives; developments in physics, electronics, machines and farm machinery.

Constructs, Models, and Systems, F. B. QUACKENBOSS, A. V. BUTTERWORTH. Paper No. 113C. Paper de-

Banishing Road Noise from Chrysler

Based on paper by

JOSEPH R. FARNHAM

Chrysler Corp.

TO ELIMINATE road noise audible in the passenger compartment of the unibody, Chrysler has developed a "speaker panel test" to track down the offending panels for treatment with sound-deadening material.

The test involves moving the air in the passenger compartment with a diaphragm mounted in a window of the car and driven by an electromagnetic vibrator. The current input to the vibrator is held constant as it sweeps the frequency range. A probe pickup which measures velocity is then placed at numerous spots on each panel. The velocities are amplified and registered on an X-Y plotter to provide a permanent record. Fig. 1 shows a representative pattern of one part of a panel before and after treatment.

Fig. 1 — Typical X-Y plots obtained in speaker panel test to determine resonant characteristics of panels responsible for road noises within passenger compartment of a unibody. Here the plots show before and after treatment.

Additional Techniques Required

Whenever possible, changes were made in panels which resulted in changing the frequencies to a point where they were no longer influencing road noises. Two areas — the roof panel and the floor pan — required greater changes than possible using this technique. Structural roof bows solved the roof panel problem by

scribes systems from three aspects: historical (from Newton and Laplace to present), philosophical (treating parallel between learning process and systems viewpoint) and practical, in which specific examples of systems are presented; it is pointed out how solutions of systems problems which contain people employ concepts and mathematical techniques, largely borrowed from physical and engineering sciences.

PRODUCTION

High Cost of Goofing, B. I. RAYSOR, H. R. BOLTON. Paper No. 111A. Approach taken by Harrison Radiator Div. of General Motors Corp., Lockport, N. Y., with regard to quality control which depends to large extent upon quality attitude of all employees; problem is approached through improved communications with employees and recognition of accomplishments made.

Research Programs for Medium Size Company, H. PELPHREY. Paper No. 111B. Description of research tools and equipment used at Michigan Tool Co., Detroit, Mich., specializing in products used in manufacturing of gears and splines; research programs are suggested by customers who wish to improve or change their products, by management and own research division.

Presented here are brief digests of recently presented SAE papers. These papers are available in full in multilith form for one year after presentation. To order, circle the numbers in the "Readers Information Service" blank on page 6 corresponding to the numbers appearing after the titles of the digests of interest to you.

Unibody

changing the natural frequency and damping out the residual vibrations, which were not changed. The floor pan problem was handled by structurally reinforcing several bad areas with strainers and then changing the remaining vibrations with the most efficient material available.

The speaker panel test does determine the panels which could be influencing the problem, but this gives no assurance that all are equally responsible. Some areas designated as bad by the test were found to have no influence on the problem during road testing. An explanation for this discrepancy may be that certain panels are far enough removed from the source of disturbance to be unexcited by road irregularities, even though they are resonant in the right frequency range.

To Order Paper No. 143C . . . on which this article is based, see p. 6.

Designing Optimum Turbopumps for Nuclear Rockets

Based on paper by **ROBERT B. CLAPPER and AUSTIN CORBIN**
General Electric Co.

EARLY NUCLEAR ROCKET research and development must insure that the major efforts toward an operational system be compatible with future propulsion requirements. A highly desired concept is one which will use a turbopump feed system and operate at high pressure and temperature. For such a system, the problems are primarily independent of the thrust level. Therefore, much of the knowledge and experience gained in developing a first nuclear rocket system will benefit the more diverse propulsion requirements of the future.

The turbopump is the heart of the propellant system. The optimum turbopump design is not necessarily the one which is lightest in weight. As a component, the pump sizing, staging, and speed are determined in conjunction with the suppression head, the delivery pressure, and the expected operating efficiency. The propellant also influences pump design. Liquid hydrogen — by far the best nuclear rocket propellant from a performance standpoint — has the disadvantage of being an extremely cold cryogenic (– 423 F) and having a density less than one-fourteenth that of water. This low density and the attendant high head needed to produce reasonable delivery pressures dictate a close look at pump staging. Although staging will increase system weight and complexity, the pump power requirements would be reduced with a resultant savings in the turbine driving fluid requirements.

Either centrifugal or axial pumps can be used. . . . Generally speaking, the axial pumping arrangement requires more stages, more dry weight, and less driving power than the comparable centrifugal unit. System operating duration would have a large bearing on the type to use.

An in-line turbopump is a most favored choice for the first nuclear rocket system. The high operating speed of the pump negates the use of a gearbox between it and the turbine. This arrangement also affords ease of assembly, fewer parts, and operating simplicity. With the speed of the turbine in common with that of the pump, only the size and number of turbine stages have to be determined.

The turbine will be the impulse type, and the size and number of stages must be optimized in conjunction with the state and type of driving fluid.

Using liquid hydrogen as the working fluid, the following are categories of turbine cycle types and their respective effects on the optimum turbine arrangements:

1. Hydrogen bleed cycle. This is operated by hot hydrogen taken off the thrust chamber at some convenient location. The gas temperature at this point must be relatively stable or the bleed gas must be mixed with cooler hydrogen to attain this stability. The hydrogen temperature used will be about 1500 F. This cycle will definitely be optimum as a pressure compounded multistage turbine. Number of stages will be influenced by system operating pressure level and the magnitude of the total impulse imparted to the vehicle. Four or more stages will be required for most applications in the foreseeable future.

An additional advantage of the bleed cycle is the thrust-producing capability of the turbine exhaust. By proper design a specific impulse of about one-half that available in the main thrust chamber can be attained by adding an expansion nozzle to the turbine exhaust duct. Thrust available from the turbine exhaust at altitude will be in the vicinity of 1% of that produced by the thrust chamber. This exhaust duct lends itself readily to a gimballed type mounting for use as a thrust vector control. In this way, during the powered portion of flight, slight vehicle and path adjustments can be made. The thrust chamber, due to the inherent weight of the reactor, doesn't lend itself to gimbal type mounting.

2. Hydrogen topping cycle. This cycle also works on hydrogen gas, but the total hydrogen flow rate is directed to the turbine after it has regeneratively cooled the nozzle and pressure shell. After passing through the turbine the total flow is passed through the reactor and then expanded in the thrust chamber nozzle. Due to the relatively low inlet temperature of the hydrogen gas (200 R), this cycle operates with a good efficiency using a one-stage turbine. The tremendous advantage of this cycle is that all of the propellant is available to produce thrust at the best specific impulse. The prime disadvantage is that the pumping system requires more power to produce the higher discharge pressure necessitated by the added system pressure drop across the turbine.

3. Hydrogen plus oxidizer cycle. This uses a bipropellant system and is quite similar to the bleed cycle. An oxidizer — such as liquid oxygen — is combusted with hydrogen gas bled off the thrust chamber at a regulated mixture ratio. Operating temperatures, pressures, and staging are similar to the bleed cycle. A major disadvantage is the need for a second propellant with its attendant plumbing and controls added to the system. A real advantage is that the elements necessary to start the turbopump are available.

To Order Paper No. 123B . . . on which this article is based, see p. 6.

Octane Number Requirements for 1958 Passenger Cars Issued by CRC

A STATISTICAL survey of octane number requirements of 1958 model passenger cars is recorded in CRC Report 337, "Octane Number Requirement Survey — 1958." It is the second step in a projected series of new design and special interest models.

Thirty-two laboratories submitted data on a total of 532 cars. These included cars in proportion to their population, plus additional cars to give at least 20 each of ten selected models.

Survey results show:

• Octane requirements of the total 1958 car population are approximately one-half octane number higher than that for the total 1957 car population.

• The tendency toward high-speed knock was less in 1958 than in 1957. Approximately 14% of 1958 cars gave maximum knock above 2,350 rpm on full-boiling range reference fuels compared to 29% of 1957 cars. In general, most cars of a given model had appreciably lower octane requirement at high speed than at low speed, but the highest requirement cars of a given model had close to the same full-boiling range reference fuel requirements at high and low speed.

• Part throttle knock results on full-boiling range reference fuels indicate that 9% of all 1958 model cars will give maximum knock at part throttle, as compared to 6% for 1957 model cars. Twenty-five to 30% of selected models J436, L436, P231, and U436 had maximum octane requirements at part throttle. Many of the cars knocking at part throttle gave the knock at manifold vacuums of 10 in. of mercury or higher and had higher than average octane requirement. Of the cars having full-boiling range reference fuel requirements of 100 Research octane number or higher, one-fourth gave maximum knock at a manifold vacuum of 10 in. of mercury or higher.

• Knock on tank fuel was reported by the owners for 22% of the cars, but was found by the observers for 35% of the cars.

Maximum octane number requirements (See Table 1) are expressed as Research octane number of the reference fuels giving borderline knock due to either spark knock or surface ignition, which ever is limiting. The requirements shown for "all 1958 cars" are weighted statistically on the basis of 1958 registration figures. (See Table 1.)

Table 1 — Maximum Octane Number Requirements

	No. Cars Tested	Octane Number for Indicated Percent Satisfied			
		50%		90%	
		PR[a]	FBR[b]	PR[a]	FBR[b]
All 1958 Cars	532	92.2	94.6	96.8	99.6
Individual Makes					
U436	25	97	99.5	100.5	104
D439	22	97	98	100	101.5
H637	21	96.5	98	99	101.5
J436	26	95.5	98	99	102
N434	26	95.5	98	98	100
S443	20	94.5	98	98	101.5
O433	25	94	97	97	100.5
G436	21	94	95.5	96.5	99
L436	22	93	97	97.5	99.5
P231	35	91.5	94	95.5	99

[a]PR = Primary reference fuels
[b]FBR = Full-Boiling range reference fuels

Reference Fuels

Two types of reference fuels were used:

(1) Primary Reference Fuel Blends — Isooctane and normal heptane meeting ASTM specifications were blended in two octane number increments from 84 to 94 and in one octane number increments from 95 to 100. Primary reference fuel blends of 101, 102, 103, 104, and 105 octane number were prepared by addition of tetraethylled to isooctane.

(2) Full-Boiling Range Reference Fuel Blends — Full-boiling range reference fuel blends were prepared by cross blending three gasolines in two octane number increments from 84 to 94 Research octane number and in one octane number increments from 95 to 105 Research octane number.

The average octane number ratings of the reference fuel blends based on data obtained by 15 of the participating laboratories and the fuel identification numbers are shown in Table 2.

Table 2 — Average Octane Number Ratings and Fuel Identification Numbers

Blend No.	Composition, Volume %			Average Octane No.	
	RMFD-93-58	RMFD-94-58	RMFD-95-58	Motor	Research
1-C-58	—	5	95	78.5	84.0
2-C-58	—	16	84	79.8	86.0
3-C-58	—	27	73	81.0	88.0
4-C-58	—	39	61	82.4	90.0
5-C-58	—	52	48	83.8	92.0
6-C-58	—	65	35	85.0	94.0
7-C-58	—	72	28	85.6	95.0
8-C-58	—	79	21	86.2	96.0
9-C-58	—	87	13	86.9	97.0
10-C-58	—	97	3	87.6	98.0
11-C-58	10	90	—	88.4	99.0
12-C-58	26	74	—	89.4	100.0
13-C-58	38	62	—	90.1	101.0
14-C-58	55	45	—	91.1	102.0
15-C-58	71	29	—	92.2	103.0
16-C-58	85	15	—	93.3	104.0
17-C-58	99	1	—	94.3	105.0

To Order CRC Report 337 . . . on which this article is based, see p. 6.

Oils in Stop-Go Service Related to Deposit, Wear

TO COMPARE the deposits, wear, and rusting resulting from oils, engines, and operating conditions, field tests of three oils (REO-80-56, REO-132-55, and REO-133-55) in stop-and-go type service were conducted by the Ordnance Corps and Coordinating Research Council. The data obtained and published in CRC 338, "Oils in Stop Go Field Service," will serve as

Continued on p. 119

SAE NEWS

New Action Set by Membership Group

AN ACTION PROGRAM to increase SAE membership is the highlight of current Membership Committee plans. Three new working subcommittees now represent the Society's diverse administrative structure, Membership Chairman W. J. Lux has announced.

These new groups are: Sections Membership Program Subcommittee; Engineering Activity Membership Program Subcommittee, and Technical Membership Program Subcommittee. Norman P. Mollinger will chair the Sections Subcommittee; W. E. Thill, the Engineering; and W. F. Sherman, the Technical.

The Sections Subcommittee will assist in membership programs and services by coordinating membership work between Sections and Groups and the Membership Committee.

SAE's 15 engineering activity committees of the Engineering Activity Board will be the area upon which the Engineering Activity Subcommittee will draw for its programs.

Interesting the large number of nonmembers on SAE Technical Committees (2000 out of 4500 men) in Society membership will be the specialized function of the Technical Subcommittee.

SAE "Briefs" from Engineering Index

THE part of SAE Journal labeled "Briefs of SAE Papers" gets close attention from something like 40% of our readers . . . and this very considerable portion of our 24,000 SAE members rates these "Briefs" as very high in both interest and value.

These columns of "Briefs of SAE Papers" — which appear every month in SAE Journal — cover EVERY paper presented before any meeting of the Society —— Section or National (assuming that a copy of the paper arrives at SAE headquarters).

The "Briefs," in addition, are part of a much broader coverage of similar subjects, which is known as the Card Index Service of the Engineering Index. In fact, the copy for our SAE Briefs is a carbon of the card used by Engineering Index in its card service.

When members ask questions about SAE references or papers on any given subject, SAE headquarters almost always suggests they save themselves time and effort by checking Engineering Index FIRST . . . because they'll find in there not only everything they can find in an SAE Journal or SAE Transactions index, but also references from a thousand other technical publications as well. Older references can be found in the big annual bound volume of Engineering Index, which most company libraries must have. . . . Up-to-last-week references are available, of course, only via Engineering Index's Card Service . . . which is broken down into 250 separate categories, so that an individual engineer *or* his en-engineering library can get exactly what is needed at minimum cost — weekly.

"Briefs of SAE Papers" are written by the Engineer Index people for SAE. These specialists do this job much better than SAE Journal editors could hope to do it.

Sir George Edwards '59 Guggenheim Medalist

SIR GEORGE EDWARDS (CBE, FRAeS, BSc, Hon FIAS), managing director, Vickers-Armstrong (Aircraft) Ltd., Weybridge, England, receives the 1959 Daniel Guggenheim Medal at SAE's National Aeronautic Meeting Dinner in New York on Thursday, April 7 . . . where he is the principal speaker of the evening.

Awarded annually for notable achievements in the advancement of aeronautics, the 1959 medal goes to Sir George for "a lifetime devoted to the design of military and commercial aircraft, culminating in the successful introduction into world-wide commercial service of the first turbine powered propeller driven aircraft."

Sir George Edwards

Sir George joined Vickers-Armstrong at Weybridge in 1935 — when he was 27. He worked in the design and drawing offices until the outbreak of war. Then he was appointed experimental works manager on Wellington, Warwick, and Windsor bombers, and other special projects. Just ten years later, he was named chief designer at Weybridge — head of the team responsible for the world famous jet-prop Viscount (which ushered in the jet age in 1948) and for the Vickers Valiant "A" bombers.

As managing director, he is presently responsible for the technical direction of the company . . . including the Viscount's "big brother" — the Vanguard, and the new pure jet VC 10 airliner.

In addition to SAE, the award is sponsored by the American Society of Mechanical Engineers, and the Institute of Aeronautical Sciences. SAE's representatives on the Board of Award are D. Roy Shoults, J. B. Wassall, and Jerome Lederer.

SAE Standards Save Millions, Huebner Estimates

$392,000,000 IS ONE ESTIMATE of the cumulative saving to industry and public on today's 70,000,000 on-the-road vehicles made possible by SAE Standards on electrical equipment alone.

Here's how Chrysler's George J. Huebner, Jr., figured it out for his audience at a recent meeting of group leaders of SAE's Cooperative Engineering Program (CEP):

> Assuming $60 as the cost of an automobile electrical equipment system; and the savings due to SAE standardization work as between 5% and 10% of individual-parts cost; the savings per car would be approximately $5.60.

This same type of estimate can be extended almost to every part of the car . . . brakes for example: On today's 70,000,000 on-the-road vehicles, the saving from SAE standardization work can be estimated conservatively at not less than $150,000,000.

More Help to Sections Is Area Coordinators Aim

SAE'S FIRST AREA COORDINATORS to provide liaison between Sections and Groups and the SAE Sections Board are in process of being organized. Fifteen nominees named by the Board's Executive Committee are being invited by Board Chairman W. F. Ford.

Each Area Coordinator will be the Sections Board's contact with a small number of Sections and Groups in his geographic area. Chosen from among Sections Board members and others with extensive experience in Section and Group administration, each Area Coordinator will attend Governing Board meetings of local units in his area twice a year. After learning the Governing Board's problems, he will have the dual function of taking its questions and recommendations to the Sections Board and of conveying to Sections and Groups ideas garnered from others. He will also keep the Governing Board posted on SAE policies as they pertain to Section, Group, and student activities.

Interchange of experiences and ideas is a prime objective of the Area Coordinators. Regional Section Officer Conferences will be an important means of getting Governing Boards in an area together for discussion sessions. These Conferences will be sponsored by the Sections Board in cooperation with one or more Area Coordinator.

Coordinators will help indoctrinate new Section and Group officers, and will be on call to answer their questions or to make suggestions. They will have ideas for student activity promotion and for special type Section meetings, as well as for making regular meetings more attractive to the local membership. They will be equipped to help establish financial programs.

Area Coordinators are appointed by the Sections Board Executive Committee to serve a one-year term, but are eligible for reappointment to serve a maximum of three terms in any one region. Experience of the first Area Coordinators group will serve as a basis for a coordinator's handbook to make the assignments easier for future coordinators.

Activity Groups Name 1960 Chairmen

AEROSPACE Powerplant Activity Committee and Aerospacecraft Activity Committee are new designations for the former Aircraft Powerplant and the Aircraft and Missiles Activity Committees, the Engineering Activity Board announced recently. The new names chosen by the two committees, the Board agrees, are more descriptive of their current and expanding interests.

Chairmen of EAB's 15 engineering activity committees — nominated by the membership of the respective committees, and approved by EAB — are:

Aerospacecraft
F. H. Sharp, project engineer, Convair Div., General Dynamics Corp.

Aerospace Powerplant
R. R. Higginbotham, staff engineer, propulsion, Advanced Research & Development, Republic Aviation Corp.

Air Transport
H. D. Hoekstra, Engineering and Mfg. Div., Bureau of Flight Standards, Federal Aviation Agency.

Body
D. C. Perkins, design coordinating engineer, Oldsmobile Div., GMC

Computer
D. E. Hart, assistant department head, Research Labs, GMC

Engineering Materials
J. H. Dunn, Development Division, Aluminum Co. of America

Farm, Construction and Industrial Machinery
W. F. Shurts, vice-president, engineering, Twin Disc Clutch Co.

Fuels and Lubricants
Gilbert Way, technical representative Western Region, Ethyl Corp.

Nuclear Energy
R. W. Middlewood, director Georgia Nuclear Labs., Lockheed Aircraft Corp.

Passenger Car
T. H. Thomas, assistant general manager Automotive Section, Bendix Products Division, Bendix Corp.

Powerplant
Gregory Flynn, Jr., head Mechanical Development Department, Research Labs., GMC

Production
C. W. Ohly, vice-president, general manager, Thompson Products Michigan Division, Thompson Ramo Wooldridge, Inc.

Science Engineering
Michael Ference, Jr., director, Scientific Lab., Ford Motor Co.

Transportation and Maintenance
F. W. Petring, chief, Vehicle Performance Branch, U. S. Department of Commerce

Truck and Bus
R. R. Noble, chief engineer, Truck Design and Development, Chrysler Corp.

Students to Aid SAE Nuclear Energy Group

A JOINT ACTION PROGRAM to stimulate increased interest in nuclear energy among engineering students has been drawn up by members of SAE's Nuclear Energy and Student Activities Committees. SAE enrolled students will be encouraged to participate in activities of the Nuclear Energy Committee by:

- Reporting on nuclear topics underway on their own campus;
- Offering questions on papers presented by the Nuclear Energy Committee, and
- Programing for their meetings speakers on nuclear subjects suggested by the Nuclear Energy Committee.

Rising interest and participation of students in the nuclear field have been indicated by several Faculty Advisors. Many engineering schools include at least a year of study in this area, so that an SAE-inspired program of cooperation with these schools should be of mutual benefit. It will make students aware of SAE's interest in the field of nuclear energy and aid the Nuclear Energy Committee in developing discussions of technical interest.

SAE Faculty Advisors have been asked to recommend or select engineering students for participation in the project.

SAE Membership At All-Time High

AN ALL-TIME HIGH of 24,211 dues-paying members at the close of 1959 has been announced by 1959 Membership Commtitee Chairman J. H. Dunn.

Applications received were well over the 1958 mark, he says . . . attesting to the ten-year steady increase in membership being experienced by the Society. 1960 Chairman W. J. Lux indicates the new role of the Membership Committee as that of "prime exponent of membership services and development."

T. L. Swansen J. E. Taylor

THROUGH a printer's error, the names of these two men were transposed under their photographs on page 111 of the March 1960 SAE Journal.

T. L. SWANSEN, vice-president, Ladish Co., and **J. E. TAYLOR**, director, Automotive Research, Gulf Research & Development Co., are both members of the 1960 SAE Engineering Activity Board, with terms expiring at the end of the 1962 administrative year.

FACTS . . .

. . . from SAE literature.

(Except where a charge is specifically indicated, SAE Journal will be glad to supply on request one copy of any of the pieces of SAE literature described. Address "Literature," SAE Journal, 485 Lexington Ave., New York 17, N. Y.)

FROM STUDENT ENROLLMENT TO SAE MEMBER is Part III of SAE's revised 23-p. booklet "How to Make the Student Branch Click."

Part I is devoted to the "how" of organizing a Branch or Club, and Part II to ways of keeping interest high.

Designed by Chairman E. P. White's Student Activities Committee of the Sections Board primarily as a guide for Student Branch officers, the booklet is being distributed also to Faculty Advisors and Section and Group Student Committee chairmen.

GROUND SUPPORT EQUIPMENT currently takes a billion dollars a year from taxpayers' money, USAF's Director of Maintenance Engineering, said recently in a message to SAE members . . . And he went on to cite the valuable service rendered by SAE's Technical Committee GSE-1 in helping to meet the technical challenge posed by current GSE requirements.

The whole story — originally in January SAE Journal — is now contained in a 24-p. illustrated booklet titled "Data on Ground Support Equipment."

OUTCOME of a luncheon meeting of group leaders in SAE's Cooperative Engineering Program is the booklet titled "Report of CEP 1960 Group Leader Luncheon."

In it, A. T. Colwell, Leonard Raymond, Ralph Isbrandt, George J. Huebner, Jr., C. F. Nixon, and Carl Sadler tell of CEP's dollar-saving value to industry . . . and how it is that every passenger car, truck, bus, airplane, tractor, earthmoving equipment, and missile has CEP content.

YOU'LL . . .

. . . be interested to know . . .

THE NEW STUDENT BRANCH at San Jose State College, San Jose, Calif., is outcome of several years of preparation on the part of students and faculty — while operating as an SAE Student Club. Student Branch charter was granted by the Board of Directors at its meeting in January.

In making application for the Charter, T. E. Leonard, head of the College's Aeronautics Department, summed up the enthusiasm of the group when he said: "It has been my pleasure to work with these boys during the past college year, and I am pleased to say that they have developed a strong, active membership. There is little doubt in my mind that they would be capable of representing the high standards of the Society. Our college administration and the members of the staff of the Engineering Department wholeheartedly support the student chapter."

Prof. Leonard is the faculty advisor. The officers of the new Branch are: D. D. Sampson, chairman; R. E. Gregg, vice-chairman; Frank Castillo, secretary-treasurer.

BETTER SERVICE TO SAE MEMBERS was the motivation that resulted in scheduling Summer Meeting in localities where the greatest number of members would get the most from the meeting. Chicago for 1960's Summer Meeting was the initial change.

Following through on the "rotation" principle, EAB announces that 1961 Summer Meeting will be held in St. Louis at the Chase-Park Plaza Hotel . . . and in 1962, Atlantic City will be the site, Chalfonte-Haddon Hall the hotel.

SAE LETTERS FROM READERS

From:
Ted Gallagher, Manager
Aviation and Defense Equipment
Sales, New York District
General Electric Co.

Dear Editor:

We fully agree with your statement in Chips (SAE Journal, February, 1960) that volume sensitive meters cannot make the transition between turbine engine fuels and that what is needed is a good, reliable mass flowmeter.

For your information, however, well over 20,000 reliable mass flowmeter systems using the momentum principle have been installed in the last decade. Such fleets as the military B-47 and B-52 aircraft, and commercial airliners such as the Lockheed Electra, Boeing 707, Convair CV-880, and Douglas DC-8 are equipped with this type flowmeter.

(Editor: You're absolutely right. We missed up on this one.)

From:
A. J. Bender (A' 59)
President
Bender's Wholesale Distributors, Inc.
Elkhart, Ind.

Dear Editor:

In reference to the picture of the new "Fiat 1500" on page 26 of the February SAE Journal, I believe you are mistaken. This is the new Maserati.

(Yes, you're right! It's the Maserati 3500/GT with body by Bertone. — Editor)

From:
G. R. Beardsley (M '50)
Manager Engine & Electrical Dept.
Truck Product Engineering
Ford Division
Ford Motor Co.
Dearborn, Mich.

Dear Editor:

It is indeed rewarding to prepare and present SAE technical papers, and it is doubly so when they provide some value in their commercial application.

W. F. Ford

1960 Chairman SAE Sections Board

W. F. FORD, chairman for 1960 of SAE's new Sections Board, is just beginning a new assignment with Continental Oil Co., where he has been in charge of engine and mechanical laboratory operations in the Research Department for 13 years.

Now he will devote himself to keeping up with long-range trends in petroleum products and to expanding his company's representation and service to industry organizations. His new assignment is assistant director, Petroleum Products Division, Research & Development Department.

Ford grew up in the oil field country and, as a boy, saw the transition from horse and mule teams to engine power for hauling in the oil fields . . . and from steam to gasoline engines for drilling as well.

But before settling down for an engineering career in his native Oklahoma, he worked for a spell on both the East and West Coasts after graduating from University of Oklahoma in 1941.

Armed with his BS in Mechanical Engineering, he worked first in experimental development and testing of aircraft engines at Wright Aeronautical in Wood-Ridge, N. J.; then spent three years designing, installing, and testing such powerplants at Douglas Aircraft.

Since 1946, he has been back at Ponca City, Okla., about 200 miles from Frederick, Okla., where he was born the year the United States entered World War I.

Ford has been active in SAE ever since he first joined as a junior member in 1947. But the breadth and depth of his service to the Society accelerated rapidly after his transfer to Member grade came in 1950. Since then, he has contributed as chairman of the Mid-Continent Section; as general chairman of the 1956 National Fuels & Lubricants Meeting; as a member of the National Meetings Committee and of the Overseas Units Committee; and successively as member, vice-chairman, and chairman of the SAE Sections committee. The latter post he held in 1959. He has been active also in coordinating Research Council work, having served on several engine, fuel and lubricant committees.

He also played an important part in getting information about SAE's Planning for Progress program distributed and understood among the membership. This work he did as Information Coordinator of the Planning for Progress Committee during the last two years of its existence.

Ford's recreational interests include such diversified activities as woodworking, mosaic tile and ceramics, car tinkering, do-it-yourself home repairs, football games . . . and travel. He particularly enjoys roaming through Mexico or the Caribbean in the winter time — if and when he gets a chance.

His wife's name is Dorothy . . . and their daughter Judy is planning to go to Oklahoma University next fall — on her way to a hoped-for post in the diplomatic service.

This is the last of three profiles covering the chairmen of the three SAE Boards under whose leadership much of the Society's work is now proceeding.

In the February issue of SAE Journal, a profile of Dr. Andrew A. Kucher, 1960 chairman of the SAE Technical Board, appeared.

In the March issue of SAE Journal, a profile of H. F. Barr, 1960 chairman of SAE's new Engineering Activity Board, appeared.

SAE Sections Board

W. F. Ford, Chairman, Product Use Laboratory, Continental Oil Co.

Term expiring at the end of the 1960

A. Wallace Denny
Vice-President
Charge of Production
Goodyear Tire & Rubber Co. of Canada, Ltd.

Otto E. Kirchner
Advisor
Airline Operations & Flight Safety
Transport Division
Boeing Airplane Co.

William F. LeFevre, Jr.
Director
Advanced Product Department
White Motor Co.

William G. Nostrand
Executive Vice-President
Winslow Engineering & Mfg. Co.

Term expiring at the end of the 1961

Paul F. Allmendinger
Chief Engineer
Instrument Division
Stewart-Warner Corp.

A. H. Easton
Professor
Civil & Mechanical Engineering Div.
Motor Vehicle Research Labs.
University of Wisconsin

Herbert A. Helstrom, Jr.
Chief Administrative Engineer
Chance Vought Aircraft, Inc.

M. J. Kittler
Executive Vice-President
Holley Carburetor Co.

Term expiring at the end of the 1962

F. Daniel Applegate
Project Engineer
Convair, Division
General Dynamics Corp.

F. Burrows Esty
Vice-President, Chief Engineer
Wisconsin Motor Corp.

Albert D. Gilchrist
Vice-President
Leece-Neville Co.

Alex L. Gray
President and General Manager
Gray Forgings and Stampings, Ltd.

SAE Sections Board
Executive Committee
W. F. Ford, Chairman

Paul F. Allmendinger
Herbert A. Helstrom, Jr.
Ernest P. Lamp
George J. Liddell
John W. Pennington
Edward P. White

SAE Sections Board
Administrative Committee
Ernest P. Lamb, Chairman

F. Daniel Applegate
Herbert A. Helstrom, Jr.
William G. Nostrand
John W. Pennington

administrative year

R. W. Rand
Staff Engineer
Research Department
Caterpillar Tractor Co.

Tom Salter
Vice-President
Engineering
Cessna Aircraft Co.

P. J. Sperry
Divisional Chief Engineer
Diesel Engineering
Construction Equipment Division
International Harvester Co.

Theodore R. Thoren
Vice-President, Engineering
Pesco Products Division
Borg-Warner Corp.

administrative year

Russell R. Noble
Chief Engineer
Truck, Design & Development
Engineering, Division
Chrysler Corp.

Leonard Raymond
Chief Automotive Engineer
Research
Socony Mobil Oil Co., Inc.

Edward P. White
Director of Licensing
International Division
Aluminum Co. of America

administrative year

Ernest P. Lamb
Executive Engineer, Administration
Engineering Division
Chrysler Corp.

George J. Liddell
Technical Assistant to Manager
Product Development Division
Sun Oil Co.

Joseph H. Overwein
Director
Laboratories
Inland Mfg. Division
General Motors Corp.

John W. Pennington
General Manager
Piston Ring & Seal Department
Metal Products Division
Koppers Co., Inc.

SAE Sections Board
Section Finance Committee
George J. Liddell, Chairman
L. L. McArthur
P. S. Myers
R. C. Norrie

SAE Sections Board
Student Activities Committee
E. P. White, Chairman
F. Daniel Applegate
A. Wallace Denny
F. Burrows Esty
W. J. Ewbank
Albert D. Gilchrist
K. W. Gordon
Michael Guidon
Russell R. Noble
R. W. Rand
G. L. Scofield
E. S. Starkman

"Planners for Progress" Cited

DESIGNING AN OPERATING STRUCTURE for SAE to parallel the accelerating trend of industry — yet retain the philosophies, practices, traditions so fundamental to SAE — was the task assigned to "Planners for Progress" some four years ago. In January 1960, SAE started operating under the new structure.

As a measure of its deep appreciation, the Society took occasion to honor the members of this Committee, and others who played a special part in the work, with individual plaques. . . .The ceremonies at which the plaques were presented are recorded here.

R. J. S. PIGOTT (left), chairman of the Planning for Progress Committee, received his plaque from SAE's Assistant General Manager Joseph Gilbert at a Pittsburgh Section meeting.

Detroit was host Section for presentation of Planning for Progress Plaques to Harry E. Chesebrough, and George A. Delaney.

Harry E. Chesebrough (left) accepts his plaque from Charles C. Dybvig.

Presentation to George A. Delaney (left) was made by Dr. Lloyd Withrow.

Arthur L. Klein (right) displays plaque presented to him by Southern California Section Chairman Charles F. Thomas.

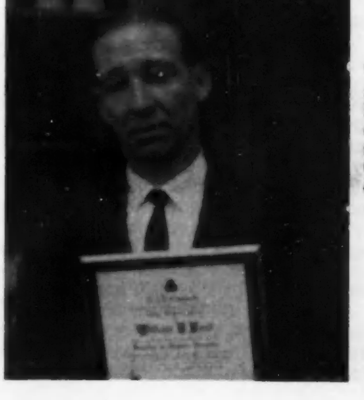
for SAE's New Operating Structure

W. Paul Eddy (left) receives his plaque from Southern New England Section Chairman E. A. Nichols.

Highlight of a San Diego Section meeting was plaque presentation to Joseph H. Famme (right) by Section Chairman E. V. Albert.

William K. Creson (right) receiving plaque from Indiana Section Chairman Melvin E. Estey.

G. Walker Gilmer (left) presents plaque to Leonard Raymond (center) at a Metropolitan Section meeting. Section Chairman Robert W. Hogan (right) participated in the ceremony.



W. F. Ford — information coordinator for Planning for Progress — displays the plaque presented to him at a Mid-Continent Section meeting.

B. B. BACHMAN received his plaque in a special "at home" delivery arranged for by the Section.

SAE's CEP NEWS

COOPERATIVE ENGINEERING PROGRAM

2¼-Inch Drop in Bumper Heights . . .

Shown in Revised SAE Standard

A SIXTEEN-INCH bumper height (from top edge) provides the optimum contact area under static and panic stop conditions, according to an SAE Bumper Height Technical Committee survey of 1959 cars, station wagons, and ½-ton trucks. This figure represents a 2¼-inch drop from the "old" SAE Bumper Height Standard which calls for a height of 18¼ inches.

The new 16-inch recommendation (see box) stems from extensive research on the part of Committee members. Led by K. A. Stonex, assistant director, General Motors Proving Grounds, this group came up with two series of bar charts which show:

- Rear bumper depth from top edge to bottom edge of all cars.
- The height of the top and bottom of the front bumper height of individual cars superimposed on array of rear bumper heights.

From these charts, bumper engagement (or lack thereof) was determined for all possible combinations of the cars studied under static and extreme dive conditions.

Actual and "ideal" bumper height distributors are compared in Fig. 1 which is keyed to the revised Standard. Fig. 2 (keyed to the 18¼ inch height) illustrates the need for adherence to the 16-inch recommendation.

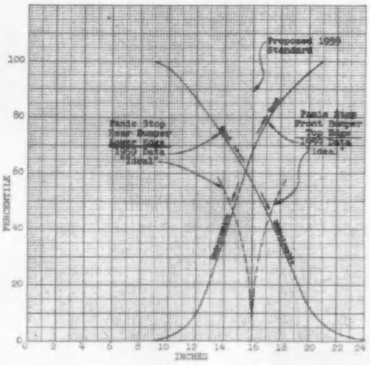


Fig. 1 — Comparison of actual and "ideal" bumper height distribution using newly revised standard.

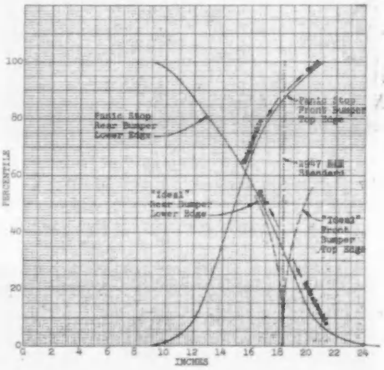


Fig. 2 — Comparison of actual and "ideal" bumper height distribution using old standard.

SAE Bumper Height Standard

UNDER full rated load and with a maximum brake stop at 5 to 10 mph, the top edge of the front bumper of passenger cars, station wagons and one-half ton trucks shall not, in normal contact areas between the treads, dive below a line 16" above road level. Any part of the rear bumper main bar lower edge between the treads on passenger cars and station wagons must not lift above this line under the same conditions.

Note: Design engineers are urged to avoid specifying extreme radii for the top edge of the front bumper in expected contact areas and for the bottom edge of the rear bumper main bar between the treads. Considerable care in this respect is needed or the anti-locking feature of the recommended dimension will be nullified. If design requirements dictate convex radii in the above areas the top of the front bumper and the bottom of the rear bumper shall be considered as the points which are tangent to lines at 45° with the road bed in planes parallel to the longitudinal axis of the car at normal load position.

Gaudaen to Serve Lighting Committee

THE SAE Lighting Committee has been added to the technical committees serviced by George Gaudaen of SAE's Detroit Office, it has been announced by M. L. Stoner, manager, Technical Committee Division at SAE Headquarters. Gaudaen succeeds Don Blanchard, who has had the Lighting Committee assignment for many years . . . and who recently was appointed a member of the Committee.

HOT WATER HEATERS — A new SAE Recommended Practice for testing and rating car heaters has been approved by the Automotive Council of the Technical Board. It describes test equipment and methods as well as methods of rating hot water cores and hot water heaters, but does not apply to complete heater systems which include components built into a vehicle body.

Designated Test Procedure and Ratings for Hot Water Heaters for Motor Vehicles, the report will appear in the 1961 SAE Handbook.

16 New SAE Aero-Space Documents

JOINING the ranks of 253 existing SAE aero-space reports are 16 new documents created to fill specific industry needs. Published last month, they are typical of the technical information developed by SAE's 115 Aero-Space Council committees. Each is classified either as an Aeronautical Standard (AS), Aeronautical Recommended Practice (ARP), or Aeronautical Information Report (AIR).

Name of Document	Description	Originating Committee
Considerations on Limiting Pressure Surge During Ground Pressure Refueling of Aircraft (AIR 74)	Deals with preventing damage caused by excessive pressure surge during ground refueling.	Aircraft and Missile Fuel, Oil and Oxidizer Systems (AE-5)
Altimeter, Pressure Actuated, Compensated — Turbine-Powered Aircraft (ARP 415)	Recommends minimum essential design and test requirements which assure safety for altimeters used in subsonic turbine-powered transports.	Aircraft Instruments (A-4)
True Mass Fuel Flow Instruments (ARP 431)	Recommends minimum essential design and test requirements which assure safety for such instruments when used in subsonic turbine-powered transports.	Aircraft Instruments (A-4)
Standard Qualification Test Specification for Aircraft Air Valves (AS 513)	Provides industry with a standard to which air valves may be subjected to prove their airworthiness in civil aircraft.	Aircraft Air Conditioning Equipment (A-9)
Low Pressure, High Temperature Pneumatic Ducting Systems (300 psi and 1000 F Maximum) (ARP 699)	Gives design, installation, testing and field maintenance criteria for specified ducting systems.	Aircraft Air Conditioning Equipment (A-9)
Emergency Placarding — Internal and External (ARP 577)	Is a design checklist for creating easily understood placards which contain signs, symbols, and/or instructions for locating and operating exits and equipment which might be used by cabin occupants under emergency conditions.	Cabin Safety Provisions (S-9)
Cabin Attendant Stations (ARP 583)	Provides a design checklist for locating and installing cabin attendant stations. ARP 583 is aimed at maximum survival probability.	Cabin Safety Provisions (S-9)
Cockpit Visibility Requirements for Commercial Transport Aircraft (ARP 580)	Is aimed at improving pilot visibility from the cockpit of transport-type aircraft.	Cockpit Standardization (S-7)
Universal Horizontal Field Maintenance Stand for 10,000 Lb. Weight Class Propulsion Units (48" and 30" Rail Gage) (ARP 581)	Is a guide to designing a horizontal field maintenance stand which is adaptable to engines of specified classes. A unique feature of this design is the two-coil gage which makes the stand easily adaptable to large or medium size turbo-jet and turbo-shaft engines.	Engine Tooling (EG-1)
Coiled Tubing (ARP 584)	Offers a convenient way to design metal tubing configurations that provide for large relative motion between contiguous points in fluid system piping.	Aircraft and Missile Hydraulic and Pneumatic Systems and Equipment (A-6)
Procedure for Determining Particulate Contamination of Hydraulic Fluids by the Particle Count Method (ARP 598)	Describes a self-checking procedure for determining particulate contaminants five microns or greater in size in hydraulic fluids by the particle count method.	Aircraft and Missile Hydraulic and Pneumatic Systems and Equipment (A-6)
Wheel (Sand and Permanent Mold) Castings, Minimum Requirements for Civil Aircraft Applications (ARP 586)	Recommends minimum quality control practice for inspecting magnesium and aluminum wheel castings for aircraft.	Aircraft Wheels, Brakes, Skid Control, and Axles (A-5)
Impulse Test Equipment for Testing Hydraulic System Components (ARP 603)	Is intended for use as a design standard to promote uniform impulse test machines.	Aircraft and Missile Fitting and Flexible Hose Assemblies (G-3)
Hose Assemblies: Aircraft and Missiles, High Temperature, High Pressure (ARP 604)	Covers hose assemblies suitable for use in high-temperature (400 F) high-pressure (3000 psi) aircraft and missile fluid systems.	Aircraft and Missile Fitting and Flexible Hose Assemblies (G-3)
High-Pressure Compressed Gas Hose Assemblies for Aircraft and Missile Ground Support Equipment (ARP 608)	Covers performance and test requirements for high pressure compressed gas hose assemblies used with aircraft and missile ground support equipment. These assemblies are suitable for use with pressure compressed air, nitrogen, and helium between – 65 to 160 F.	Aircraft and Missile Fitting and Flexible Hose Assemblies (G-3)
Synthetic or Natural Rubber Lined Pneumatic Hose Assemblies — Aircraft (ARP 610)	Gives design, procurement, and test requirements for 3000 psi hose assemblies used in aircraft pneumatic systems.	Aircraft and Missile Fitting and Flexible Hose Assemblies (G-3)

LINKED with the release of the above is the revision of ten existing SAE aeronautical reports. Included are:

Name of Document	Reviewing Committee
AS 1A — Altitude Graphs, Aircraft Reciprocating Engine Performance	General Standards for Aircraft Engines (E-21)
ARP 2A — Horsepower Correction Formulae	"
AS 20B — Definitions, Aircraft Reciprocating Engine Performance	"
AS 107C — Surface Finish (RMS) (Inactive for new design after June 1, 1960. Use AS 291B)	"
AS 177A — Operating Instructions for Aircraft Engines (Preparation of)	"
AS 291B — Surface Roughness (AA)	"
ARP 217A — Testing of Prototype Airplane Air Conditioning Systems	Aircraft Air Conditioning Equipment (A-9)
AS 407B — Fuel Flowmeters	Aircraft Instruments (A-4)
ARP 681A — Engine Performance Presentation for Use on High Speed Digital Computers	Engine Performance Presentation for Electronic Digital Computers (S-15)

To Order the Above . . . turn to page 6.

Note: An index of SAE's 269 Aeronautical Standards, Recommended Practices, and Information Reports is available free of charge from SAE Headquarters, 485 Lexington Ave., N. Y., 16, N. Y.

SAE's CEP News

Cooperative Engineering Program

Gurski, Nutt and Ogden Head Standing Committees of Technical Board

Gurski

Nutt

Ogden

THREE experienced SAE technical committeemen will head the Technical Board's standing committees in 1960. Joseph Gurski, Harold Nutt, and E. B. Ogden will lead the Technical Committee Guideposts Committee, Publication Policy Committee, and Certificates of Appreciation Committee, respectively.

Joseph Gurski, a 1960 SAE Director and manager of Ford's Chemical and Metallurgical Laboratory Services, is, with the help of fellow Guideposts Committee members, tying up the details of a practical guide to technical committee operations. Soon to be distributed to new and old committeemen alike, the guide will contain practical aspects of committee operations as well as overall principles and philosophies.

The Publication Policy Committee will have at its helm **Harold Nutt**, president of Borg-Warner's Borg and Beck Division. The authority of this group extends to creating publication policy for *all* SAE ground vehicle technical committee reports as well as recommending how and when such material should be published. One outstanding PPC accomplishment has been issuance of a booklet, "How to Prepare Good SAE Technical Reports."

As head of the Certificates of Appreciation Committee, **Bert Ogden**, vice president of Equipment Development at Consolidated Freightways, Inc., and his committee will continue the yearly practice of selecting those who deserve special Technical Board recognition for contributions made to technical committee work.

Schrum Heads Body Engineering Committee

Schrum

DONALD J. SCHRUM, who is a member of the 1960 SAE Board of Directors as well as a body development engineer at Studebaker-Packard, became chairman of SAE's Body Engineering Committee in January. He succeeds J. C. Widman, manager of Ford's Advanced Body Engine Department.

With **H. J. Anschuetz**, Aero-Detroit, Inc., as 1960 vice chairman, Schrum will foster the Committee's development of a motor vehicle glazing manual which is to contain basic information on front and rear vision, strength requirements, and light transparency. The Committee is also completing a detailed revision of the SAE Seating Manual (TR-135) which is expected to be available next fall.

Chairman Schrum's engineering career began in 1936 when he joined Studebaker-Packard as a body design engineer. During World War II, he worked on military tank development for the Army Ordnance Department and was an instructor at the University of Notre Dame.

New SAE Standard Promotes Car Ground Clearance

OVERHANG and underclearance of cars, station wagons, and half-ton trucks have long presented problems to designers of streets, driveways, and parking facilities. To help reduce these problems, the SAE Bumper Heights Technical Committee has come up with optimum minimum approach, departure, and ramp breakover angles which, if adhered to, will assure compatibility between motor vehicle and highway configuration.

The recommendations given in the new Standard are based on a Committee study of 49 distinctive 1959 American makes and models. Fig. 1 shows the percentile distribution of approach, departure, and ramp breakover angles for the vehicles studied.

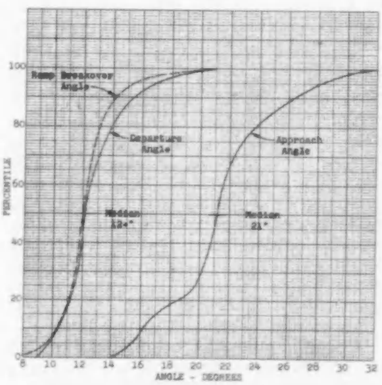
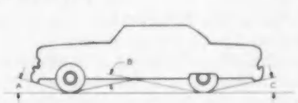


Fig. 1 — The percentile distribution of approach, departure, and ramp breakover angles of a 1959 study by the Bumper Heights Technical Committee are shown above.

New SAE Standard Approach, Departure, Ramp Breakover Angles

UNDER full rated load, the minimum approach, departure, and ramp breakover angles as indicated below shall be as follows for passenger cars, station wagons and ½ ton trucks:



A. Approach Angle — 16°
B. Ramp Breakover angle — 10°
C. Departure Angle — 10°

SAE MEMBERS

Wilson

Ogden

Colwell

Littlewood

DR. ROBERT E. WILSON, former chairman of the board of Standard Oil Co. of Indiana, has been named by President Eisenhower to be a member of the Atomic Energy Commission.

Wilson will fill the vacancy created in the five-man commission by the death of **Harold S. Vance.** He will complete Vance's term and serve a five-year term of his own.

He has had considerable experience in the activities of the AEC having served on the commission's general advisory committee since shortly after the commission was created in 1947. He has also served on the AEC's Weapons Subcommittee.

A chemical engineer with an industrial and academic background, Wilson has received honorary degrees from many colleges for his achievements as an industrial scientist, chemical engineer, and inventor.

Wilson served as chairman of the board and chief executive officer of the Standard Oil Co. of Indiana from 1945 until his retirement in 1958.

An SAE member since 1921, Wilson served for several years on the finance committee.

E. B. OGDEN, vice-president in charge of equipment development at Consolidated Freightways, Inc., has been made an honorary member of the Equipment Committee of the Regular Common Carrier Conference in recognition of his contributions as the first chairman — 1957–1959 — of the Conference's subcommittee on Maintenance.

JACK F. WHITAKER has become president of Whitaker Cable Corp. Previously he was executive vice-president.

ARCH T. COLWELL, president of SAE in 1941, has been honored by Thompson Ramo Wooldridge, Inc. of which he is vice-president, by designation of its new engineering center as the Arch T. Colwell Engineering Center. The building, with two stories and basement has 32,000 sq ft of space; is constructed of aluminum and glass. It is to be the first unit in a $5,000,000 building program. When the Colwell Engineering Center is completed a portrait of Colwell by Edith Stevenson Wright will be placed in the lobby.

Colwell, who has been chairman of SAE's Finance Committee for many years, has headed TRW's engineering research and development as a vice-president and director for 30 years.

WILLIAM LITTLEWOOD, vice-president, equipment research, American Airlines, Inc. has been elected a director of Marquardt Corp. of Van Nuys, Calif. Littlewood was president of SAE in 1954.

ANDREW A. KUCHER, Ford's vice-president of engineering and research, is serving this year as chairman of the Metropolitan Detroit Science Fair. He was a main speaker at the banquet held on April 7 in connection with the fair. Kucher is 1960 chairman of SAE's Technical Board.

PAUL W. KNAEBEL has joined the Ceylon Institute of Scientific and Industrial Research as a member of the U. S. Operations Mission to Ceylon, a part of the International Cooperation Administration.

Knaebel was previously senior industrial engineer at Byron-Jackson Division, Borg-Warner Corp.

LEWIS C. KIBBEE has been named director of the newly created combined Engineering Department at American Trucking Associations. The new department includes staff sections concerned with automotive, highway, and radio and communication engineering.

Kibbee, who has been a member of ATA engineering staff since 1949, will continue as chief automotive engineer and chief of the automotive engineering section. He is currently an SAE director.

L. PAUL ATWELL has been appointed product manager, Spark Plug Division, Electric Autolite Co. Atwell joined Autolite in 1949 as field engineer and has served them as assistant chief ignition engineer and chief spark plug engineer.

JOE F. CULP has joined General Controls Co. as assistant branch manager for the firm's San Francisco factory branch office. In this position he will handle sales of automatic controls for aircraft. Formerly he was regional manager, field engineering, for Kansas City, Mo. office of Lord Mfg. Co.

JOHN G. HOLMSTROM has been assigned new responsibilities at Pacific Car & Foundry Co. He is devoting full-time to the advance engineering and designing of on and off-highway motor trucks for Kenworth and KW-Dart Truck Co. Divisions. His engineering and management career with Kenworth and Pacific Car dates from 1923.

LEROY SIMPSON has joined the aviation consultant firm of R. Dixon Spears Associates, which is now located at Manhasset, Long Island.

Previously Simpson was superintendent of operation engineering for Pacific Division of Pan American World Airways. In this post he was responsible for technical aspects of operations planning and introduction programs for Boeing 707 and Douglas DC-8 jet transports.

THOMAS R. KILGUR, assistant chief electrical engineer at Chrysler Corp., presented a progress report on automotive lighting "Some Results of Cooperative Vehicle Lighting Research" at a meeting of the Highway Research Board Night Visibility Committee January 12.

GEORGE ANISMAN has been appointed manager of research and product planning at Telecomputing Corp.'s Whittaker Controls Division. Previously he was manager of applications engineering of Sundstrand Turbo Co.

LEO W. TOBIN, JR., has been appointed to an important executive post in the Defense Systems Division of General Motors Corp. His specific duties will be announced later. Tobin has been manager of AC Spark Plug division's operations at Milwaukee.

HOLLISTER MOORE, manager, Membership and Sections Division, SAE Headquarters staff, is the author of an article titled "To Honduras for Luncheon" published in *Freighter Travel News* for February, 1960. The *News* is published by the Freighter Travel Club . . . and Moore's article narrates the events of a 10-day freighter vacation with his wife and son on the S. S. Calamares.

ROBERT SCHILLING has been appointed to a key engineering assignment with Adam Opel, German car and truck manufacturing subsidiary of General Motors Corp. A native of Germany, he his directed research and development programs at the Chevrolet Motor Division for the last four and half years.

FRANK J. WINCHELL has been named to succeed **Robert Schilling** as assistant chief engineer in charge of research and development at Chevrolet Motor Division, General Motors Corp. He had served as staff engineer in the research and development department since early 1959.

PAUL H. RICHARD, for the last five years automotive liaison representative for E. I. du Pont De Nemours & Co.'s Petroleum Chemicals Division in Detroit, has been named head of a new automotive division in the company's Petroleum Laboratory.

MAX W. CORZILIUS has been named to succeed **Paul H. Richard** as liaison representative for E. I. du Pont de Nemours & Co.'s Petroleum Chemicals Division. Since 1951 Corzilius has been research engineer for the company's Petroleum Laboratory.

DAVID D. BOWE, formerly assistant sales manager for military aircraft products of Aeroproducts operations, Allison Division of General Motors Corp., has joined Republic Aviation Corp. as manager of the company's Dayton, Ohio office.

BERTON KAROL, manager of Automotive Division of Oxy-Catalyst, Inc., will speak April 27 at the 21st annual meeting of the American Industrial Hygiene Association at Rochester, N. Y. on "Automotive Exhaust Fume Purification by Catalytic Oxidation." Karol also discussed this subject before the April 1 meeting of West Virginia Chapter of American Society of Safety Engineers.

Kibbee

Atwell

Culp

Holmstrom

"Arts and the Faculty," a section of MIT's Report of the Dean of the School of Engineering, carries announcement of personal achievements outside the academic realm of two SAE members of MIT's faculty.

- **EDWARD S. TAYLOR**, Department of Aeronautics and Astronautics, exhibited a silver salad service at the Boston Arts Festival.
- **C. FAYETTE TAYLOR**, Department of Mechanical Engineering, contributed "The Flying Dutchman" to the sculpture exhibit of Harvard's Busch-Reisinger Museum.

— continued —

SAE Members

— continued —

G. BRUCE WILSON has been appointed eastern regional sales manager for Norma-Hoffmann Bearings Corp. Since 1958 Wilson has been Detroit district manager for Norma-Hoffmann.

Prior to that he was sales engineer for New Departure Division, General Motors Corp. and Detroit district manager for Waterbury Mfg. Division, Chase Copper & Brass Co.

Wilson

Todd

Freitag

Bohne

Fletcher

ROBERT A. TODD has been appointed vice-president in charge of engineering for All-O-Matic Mfg. Corp. Previously he was employed by Moraine Division of General Motors Corp. where he specialized in the development and production of many innovations in friction materials for automatic transmissions.

WALTER H. FREITAG has been assigned to the newly created sales office in Portland, Ore. of Vickers, Inc. Freitag has had over 12 years experience in the development and use of off-highway equipment and other mobile equipment applications.

J. R. BOHNE has been appointed sales engineer at Dana Corp. Before joining Dana two and a half years ago, Bohne served D. H. Overmeyer Warehouse as assistant to operations manager. He graduated from University of Toledo and is currently attending their graduate school.

R. E. FLETCHER is now chief engineer of Mechanical Transmission Division at Dana Corp. Fletcher joined Dana in 1949 and has served them as transmission engineer and assistant chief engineer of Transmission Division.

NORMAN REVENAUGH has become assistant chief engineer for production engineering at Dana Corp., Mechanical Transmission Division. Previously he was project engineer.

LOUIS STUCKEY has become assistant engineer for advanced engineering, Dana Corp., Mechanical Transmission Division. He was project engineer prior to his new appointment.

A. M. FISCHER has become manager of sales technical services, Anti Freeze Department, Union Carbide Consumer Products Co., Division of Union Carbide Corp. Formerly he was division manager for automotive products at National Carbon Co.

MARSHALL G. WHITFIELD has become president of Al-Fin Corp. in Bethel. Conn. Formerly he was president of Whitfield & Sheshunoff, Inc.

CHARLES G. STERLING has become chief engineer for bumpers at Research and Development Division, Rockwell-Standard Corp. Previously he served Kaiser Aluminum & Chemical Corp.

D. A. GLENDENEN, formerly field engineer, is now manager of manufacturers sales engineering, Firestone Tire & Rubber Co.

THEODORE A. SUNDIN has become project engineer with advanced weapon systems group at Allison Division, General Motors Corp. Formerly he was customer service engineer for Convair Fort Worth Division of General Dynamics Corp.

W. L. BRUCKART, formerly manager of sales at Refractomet Division of Universal-Cyclops Steel Corp., is now a consultant.

JOSEPH B. BOYNTON has been named executive vice-president and general manager of F. J. Egner & Son in Galion, Ohio. Formerly he was assistant vice-president and superintendent of equipment and garages for Motor Cargo, Inc.

MARVIN SILVER, formerly an engineer for General Electric Co., is now flight test engineer at Convair Astronautics.

BEN S. BARRETT, formerly sales manager of Gasket Division of Victor Mfg. & Gasket Co., is now sales manager in charge of industrial sales.

WILLIAM FRED ANDERSON has become draftsman with Thiokol Chemical Co. Previously he was tool designer for Boeing Airplane Co.

GORDON W. GOODWIN has become product engineer for Aeroquip Corp. Formerly he was project engineer at Yard-Man, Inc.

KENITH G. STRUNK has become vice-president in charge of research and engineering at Textile Machine Works. Formerly he was director of engineering at Breeze Corp., Inc.

RICHARD W. KING is now service publications writer for Douglas Aircraft, Inc. Formerly he was instructor, customer field service for Northrop Corp.

JAMES W. WRIGHT, previously manager of mechanical engineering section, Missile Division, Chrysler Corp., is now senior research engineer at Autonetics Division of North American Aviation Corp.

HAROLD OSLICK, previously structures engineer at North American Aviation, Inc., is now designer for analytic section of Pratt & Whitney Aircraft.

RALPH C. BROWN has become sales engineer at Chicago District office of Aluminum Industries, Inc. Previously he was resident engineer for Minneapolis Moline Co.

HERBERT G. HOEFLER, JR. has become sales engineer and assistant to vice-president and general manager at Atlas Controls, Inc. Previously he was project manager and assistant to general manager at Clifford Mfg. Co., Division of Standard-Thompson Corp.

KAI H. HANSEN has been given charge of chassis design of all passenger cars for Chevrolet Motor Division, General Motors Corp. A 21 year veteran of General Motors engineering, Hansen played a major role in development of the Corvair.

NEWELL H. McCUEN, who has directed passenger car chassis and transmission design for Chevrolet Motor Division, General Motors Corp. since 1956, has been selected for an important assignment in the engineering headquarters of GM overseas operations in Detroit.

RANDOLPH. L. STRICKLAND has become part owner and sales engineer of Rapid Hard Chrome Service, a newly formed company which will plate products of other companies. He is also secretary and treasurer of the corporation. His former position was research engineer for Detroit Aluminum & Brass Corp.

CARLTON H. SWANSON has been appointed factory manager of Eaton Mfg. Co.'s Valve Division. He joined the company in January 1958 as the division's engineering manager.

P. I. BROWN, previously research engineer at California Research Corp., is now group supervisor, engine Lubricants Division, Richmond Laboratory.

WARREN L. MOODY, previously field test representative, is now applications engineer for Detroit Diesel Engine Division, General Motors Corp.

LEO E. SCHAMADAN, JR. has become works manager with Snap-Tite, Inc. Formerly he was department head at Cleveland Graphic Bronze Division of Clevite Corp.

BRUCE SMITH recently retired as vice-president of Ryan Aeronautical Co. He is now living at 4515 Alhambra Street, San Diego 7, Calif.

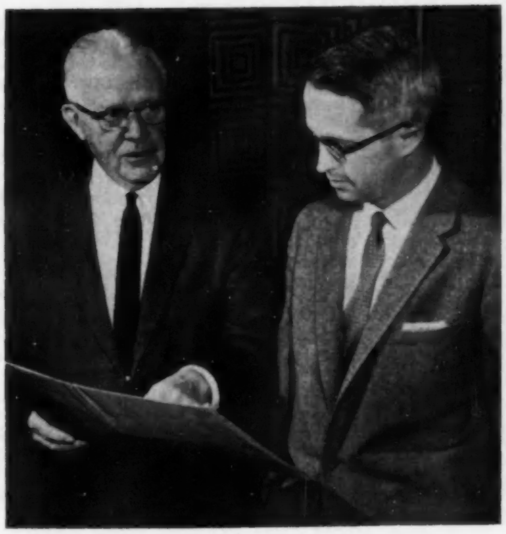
RAY E. HOFFMANN has been appointed sales engineer in the Detroit district for Aetna Ball & Roller Bearing Co. Previously he was product design engineer, specializing in bearing applications at Ford Motor Co.

ARTHUR R. BONVOULOIR has become foreman of quality assurance at General Electric Co. Formerly he was research and development engineer for Brummer Seal Co.

SAE Father and Sons:

In 1946–1947, **E. W. CAVE** (at right), was chairman of SAE Mid-Continent Section. Today his son, **WAYNE CAVE**, is student chairman of the Oklahoma State University SAE Student Section.

The younger Cave attended the South Dakota School of Technology for two years, was in the U. S. Army Corps of Engineers for three years, and is studying to complete his Mechanical Engineering degree. The senior Cave was recently named director of aviation sales at Continental Oil Co. Formerly he was assistant director of technical services.



H. FOLLETT HODGKINS (left), chairman of Lipe-Rollway Corp., updates his son, **H. FOLLETT HODGKINS, JR.**, on recent company progress. H. Follett, Jr. has been a vice-president of Rollway Bearing Co. since February 1959. He recently completed a year of advance training in business administration at Massachusetts Institute of Technology under an Alfred P. Sloan Fellowship.

Hodgkins Sr., a 30 year member of SAE, has served two terms as chairman of SAE Syracuse Section.

C. W. GENSON has joined Master Electric Division of Reliance Electric & Engineering Co. as gear engineer. Previously he served J. I. Case Co. as staff engineer for transmissions.

JOSEPH A. HOPKINS, previously national accounts coordinator, is now regional merchandising manager at Ethyl Corp.

PETER VISSER has become development engineer for Warner Gear Division of Borg-Warner Corp. Formerly he was an engineer for Fuller Mfg. Co.

LOUIS F. POLK, SR., president of The Sheffield Corp. and director and vice-president of Bendix Aviation Corp., is presently on leave of absence because of personal reasons.

He is acting in a consulting capacity, still retaining his membership on the bendix board and his officerships including presidency of Sheffield. Later in the year, he intends to again be very active although retaining more flexibility in daily schedule.

— continued —

SAE Members

— continued —

M. B. HAMMOND, a vice-president of Rockwell-Standard Corp. since 1941, has been named to the newly created position of vice-president — bumper group sales. In this position he will coordinate and supervise the company's entire bumper sales efforts.

Hammond

Reggio

Robertson

Powers

Swanson

FRANK P. REGGIO has been made director of product development at Permatex Co., Inc. Reggio joined the company in 1954 as industrial development engineer and was formerly industrial sales manager.

T. A. ROBERTSON, former manager of tire engineering at Firestone Tire & Rubber Co., has added new responsibilities. He is now manager of tire engineering and development.

R. P. POWERS, previously development engineer, is now manager of tire testing and advanced engineering at Firestone Tire & Rubber Co.

CARLTON H. SWANSON has been appointed factory manager of Eaton Mfg. Co.'s Valve Division. Previously he was the division's factory manager.

R. DALE LINT has become division representative with headquarters in Reno, Nev. for Union Oil Co. of California. Formerly he served them as assistant to manager of operations.

NORMAN KASSCHAU has been appointed sales manager for Automotive Rentals, Inc. Formerly he served Ford Motor Co. as manager of Fleet Engineering Department.

L. L. BALDWIN has become manager of sales engineering, truck tires at Firestone Tire & Rubber Co. His former position was tire development engineer.

A. D. LODGE, previously supervisor of technical services department at Ohio Oil Co., is now manager of commercial and special products sales department.

W. E. MacDONALD has been appointed to succeed **A. D. Lodge** as supervisor of technical services department at Ohio Oil Co. Formerly he was sales engineer of the department.

THOMAS B. ROSCOE has joined Boeing Airplane Co., Pilotless Aircraft Division as tool and production planner. Previously he served Curtiss-Wright Corp., Curtiss Propeller Division as field service representative.

ROBERT E. FIDLER has joined Long Mfg. Division of Borg-Warner Corp. as sales representative. Previously he was employed by Michigan Division, Thompson-Ramo-Wooldridge, Inc. as sales manager for new products.

DONALD LEE WILLOUGHBY, formerly product designer at Chrysler Corp., is now project engineer for Autocar Division of White Motor Co.

GEORGE H. FREYERMUTH has become a partner of Dupree & Freyermuth. Formerly he was executive vice-president and director of Esso Export Co.

C. W. GENSON is now gear engineer for Master Electric Co. Formerly he served J. I. Case Co.

CHASE MORSEY, JR. is now district sales manager at Livonia, Mich. for Ford Division, Ford Motor Co. Formerly he was general marketing manager for Lincoln-Mercury Division.

DAVID B. OSBORN has been named production engineer for Locomotive & Car Equipment Department, General Electric Co. His former position was design engineer for Jet Engine Department.

WILLIAM NAGY has been appointed project engineering supervisor for Aerospace Division, Boeing Airplane Co. Formerly he was propulsion system design section manager at Chrysler Corp.'s Missile Division.

F. B. JOHNSON has been named manager of PMS Ballistic Shell at Lockheed Missile & Space Division, Lockheed Aircraft Corp. Previously he served Lockheed as manager of military special products at their Georgia Division.

GERALD L. McARTHUR has become senior engineer for mechanical development at Bendix Aviation Corp., Research Laboratories Division. Previously he served Chrysler Corp.'s Missile Division as head of systems engineering department.

L. J. GALATI has become supervisor of aircraft engineering for Southern Airways, Inc. Formerly he was hydraulic engineer at Delta Air Lines.

HORACE H. CHRISTENSEN is now manager of advance space navigation engineering at General Electric Co.'s Light Military Electronics Department. Previously he was manager of flight control application engineering.

JOE C. SHAW has become project engineer for Young Radiator Co. Previously he served J. R. Meek Co. as sales engineer.

ARTHUR E. ELLIS, formerly advanced design engineer for Ford Motor Co., is now employed by the Van Keuren Co. as senior design engineer.

EUGENE J. FAUST has been appointed associate engineer for Haloid Xerox, Inc. Formerly he was design engineer at Ballastic Research Laboratory, Aberdeen Proving Ground, Md.

A. P. PODGES has been appointed director of quality control for Chrysler Corp.'s Car and Truck Assembly group. Podges joined Chrysler in 1957 after 23 years in the automotive industry. His most recent position was production manager of Imperial Assembly plant.

T. J. EMMERT is now vice-president, North American Operations at Massey-Ferguson, Ltd. in Toronto. Previously he was associated with the Ford Motor Co. of Canada.

MYRON M. SCHALL has been appointed assistant manager of research and development at Dana Corp. His previous position was assistant chief engineer of Hydraulic Transmission Division.

JAMES W. VOTH, previously designer with Allis-Chalmers Mfg. Co., is now project engineer for Red Jacket Mfg. Co.

CHARLES R. CAMPBELL is now manager of St. Louis Truck Division of The Hertz Corp. Previously he served Hertz in a similar capacity in Cincinnati. Prior to joining Hertz in 1958 he was president and general manager of Columbia Truck Leasing.

WARREN F. KOEPSEL has become research engineer at Caterpillar Tractor Co. Previously he was project engineer at the Jet Engine Department of General Electric Co.

GRANT W. KELLER, previously branch manager, is now senior field engineer at Ensign Carburetor Co., Subsidiary of American Bosch Arma Corp.

WILLIAM R. HUBKA, previously service salesman, is now service manager for The White Motor Co.

CLARENCE N. OHASHI has become project engineer at Cook Bros. Equipment Co. Formerly he was detail project engineer for General Motors Corp.'s Truck & Coach Division.

PATRICK WALLACE, formerly sales engineer at Continental Aviation & Engineering Corp., has joined the sales and marketing administration of Radio Corp. of America.

EDGAR S. HUGHES, previously development engineer with Ford Motor Co.'s Truck Division, is now senior advanced design engineer for Massey-Ferguson, Inc.

LEIGH E. DUNN, director of Test Division at Marquardt Corp., has added responsibilities as director of the company's newly formed Facilities Engineering Division.

MARSHALL DEAN KLINGER has become associate engineer at Auto Research Laboratories, Inc. Previously he was supervisor of consumer sales, Sinclair Refining Co.

WILLIAM A. THOMAS, formerly field engineer at Goodyear Tire & Rubber Co., is now executive accountant at the company's Manufacturers' Sales Department.

JOHN S. HAHN is serving the United States Air Force as missile propulsion design evaluation engineer at Norton Air Force Base, San Bernardino, Calif. Previously he was liaison engineer at Rohr Aircraft Corp.

HARRY B. BIERSDORFER has become manager of market research at Diamond Chain Co., Inc. Formerly he served them as district manager for their Cleveland territory.

JOSEPH F. BAKEL has become senior product engineer at General Electric Co.'s Specialty Control Department. Previously he was hydraulics engineer for Bendix Aviation Corp.

WILLIAM P. TOLBERT, JR., previously chief engineer at Anthes Force Oiler Co., is now production engineer for General Metal Products Co. In this capacity he will act as assistant to the vice-president for engineering.

L. O. WARFIELD, who was formerly concerned with district sales, is now a sales engineer for American Oil Co.

W. A. FRITSCH, previously chief draftsman, has become assistant to director of product at Thew Shovel Co.

A. LEIGH TAYLOR has become manager of Protective Coatings Division of R. M. Hollingshead Corp. at Camden, N. J. Formerly he served R. M. Hollingshead Co. of Canada, Ltd. in a similar capacity.

GORDON R. STONE, previously project engineer for U. S. Information Agency, is now senior designer engineer at Convair Astronautics.

DIETER K. SCHMIDT, formerly mechanical engineer at The Eimco Corp., is now mechanical engineer at Food Machinery & Chemical Corp.

DON A. PLETT has been appointed manager of product design at Cincinnati Division, Bendix Aviation Corp. Previously he was general manager at Kinetics Corp.

HEINRICH DAVATZ, previously design engineer at International Harvester Co., is now design engineer for AiResearch Mfg. Co. of Arizona.

Obituaries

GOULD ALLEN . . . (M'12) . . . representative for Lipe-Rollway Corp. . . . died January 18 . . . born 1875.

L. C. ATCHISON . . . (M'49) . . . assistant director of research, Denver & Rio Grande Western Railroad Co. . . . died February 6 . . . born 1901.

T. L. BLACKWELL . . . (M'56) . . . sales promotion manager for Hart Battery Co., Lt. in Quebec . . . died November 9 . . . born 1902.

GEORGE W. BORG . . . (M'15) . . . chairman of board, Amphenol-Borg Electronics Corp. . . . died February 28 . . . born 1887 . . . invented Borg automobile clutch in 1911 . . . formed Borg & Beck Co. (which is now Borg-Warner Corp.) and George W. Borg Corp. (which is now Amphenol-Borg Electronics Corp.)

ALFRED GASSNER . . . (M'23) . . . general manager and chief engineer, Fairchild Kinetics Division, Fairchild Engine & Airplane Corp. . . . died October 25 . . . born 1893.

HARRY PELPHREY . . . (M'43) . . . director of research at Michigan Tool Co. . . . died February 18 . . . born 1902.

ROBERT J. PETERS . . . (M'19) . . . chief metallurgist, Warner Gear Division, Borg-Warner Corp. . . . died February 27 . . . born 1896.

A. T. ROBLIN . . . (M'51) . . . Quebec Division manager, Imperial Oil, Ltd. . . . died December 21 . . . born 1896.

EDWIN A. ROBERTSON . . . (M'18) . . . retired . . . died January 28 . . . born 1886.

ROBERT W. RENWICK . . . (M'49) . . . engineer, Ford Motor Co. . . . died February 25 . . . born 1921.

ARTHUR E. SMITH . . . (M'38) . . . president of Smith & Gregory . . . died February 14 . . . born 1911.

LEO S. SULLIVAN . . . (M'56) . . . vice-president in charge of sales at Russell Mfg. Co. . . . died February 11 . . . born 1897.

Rambling . . .

Through The

GMC's TWIN-SIX truck engine is an uncommon cylinder arrangement and the V-6 is even more unusual, according to C. V. Crockett, (below) chief engineer GMC Truck and Coach Division who spoke at **Detroit Section** February 8.

These configurations, however, were chosen after much study. These engines deliver high torque at low speed but this decreases as speed increases. This characteristic gives great satisfaction in driving a truck, because as it is driven up hill it dips into the grades as the speed decreases, reducing gear shift.

Engines have large reserve power and thus permit use of a 5-speed transmission instead of the usual 8 or 10 forward speeds used on trucks of comparable size.

Interchangeability of parts, Crockett said, is a major advantage in this engine series. Althogether 73 major parts are interchangeable among the 6-cylinder engines and 56 parts interchangeable among all of the engines.

PAST SAE DIRECTOR Walter E. Thill, chief engineer of Federal-Mogul-Bower Bearings, Inc. spoke at **Hawaii Section** February 16 on ball and roller bearings. He is greeted (above, right) by George Wheelwright, chairman of program committee.

TWO PAST SAE PRESIDENTS Ralph Teetor (left) and Leonard Raymond talk over old times at **Indiana Section's** February meeting. Raymond gave a short talk at the meeting about his recent European trip.

The A3D JET ATTACK BOMBER is powered by two PW J-57 turbo-jet engines. This bomber was one of the many types of aircraft viewed by members from **SAE Student Branch, Aeronautical University, Chicago,** who toured Glenview Naval Air Station, Glenview, Ill. on January 6.

DEVELOPMENT OF MILITARY VEHICLES is governed by: (1) *tactics* which are handed down by the army chief of staff, (2) *environmental conditions* — vehicles have to "live" anywhere — and (3) *technological advantages* in component vehicles, Edward F. Blackburne, deputy chief of Engineering Division of Ordnance Tank Automotive Command, told **Western Michigan Section** February 2.

Tactics, the largest governing factor in development of vehicles, have changed in recent years, Blackburne said. Tactics from World War I were used until World War II. Originally the tank was utilized to support the infantry, but during World War II the tank became a mobile force and a striking force. Since World War II there has been an active campaign to develop the tank.

New type weapons have required different mobilization of armament — it can not be centralized. An armament dispersal pattern must be used, and the forces massed after the enemy has struck. This has become important with the advent of atomic warfare.

Ragnar Hokanson, a student at University of Washington, spoke at **Northwest Section's** student night January 26 on "Performance Testing of Heavy Duty Trucks." Hokanson was a truck fleet owner before entering school.

Col. David G. Simons who was pilot of the mammoth balloon which ascended over 101,000 ft. in Operation Man-high spoke of his trip into space at **South Texas Group** January 25. Simons, chief of Bioastronautics, School of Aviation Medicine, Brooks Air Force Base, is greeted (above left) by Richard Woodbury, group chairman.

Sections

"HEAT TRANSFER IN ELECTRONICS" and **"DIRECT CONVERSION OF HEAT TO ELECTRICITY"** will be subjects of a two-day lecture series at **Southern Methodist University**, Dallas, on May 13 and 14.

Dr. Joseph Kaye, director of MIT"'s Research Laboratory, will be the lecturer. Dr. J. P. Holman, Department of Mechanical Engineering, Southern Methodist University, Dallas 5, Texas, is in charge of arrangements.

"This advanced technology seminar will include discussion of fundamental principles, and necessary notes and books will be furnished," according to Harold A. Blum, associate professor, Mechanical Engineering Department, SAE's Student Branch faculty advisor at Southern Methodist University.

DOUGLAS DC-8 PLANE was designed not only with the passengers in mind, but more important, it was designed for the crew which is responsible

for safety and comfort of the passenger, according to John F. Martin, assistant director of flight at Douglas Aircraft Co., who spoke at **Southern California Section** February 8.

Some of the extras of the DC-8 include: (1) low speed stability with excellent control, (2) high-speed air for rain removal instead of windshield wipers (3) blow-away jet on each engine to break vortex, (4) anti-skid protection for tires with heat plugs to protect against blowouts and a foot thumper to warn the pilot of maximum braking. (5) excellent visibility in and out of the cockpit and excellent cockpit lighting.

John F. Martin (above right) talks with George F. Douglas, vice chairman of aeronautics.

COMPUTERS can not only be programmed to play chess, but with the help of special circuits can learn to play a better game of chess than their human opponent, George A. Porter, vice-president of Detroit Edison Co. told **Detroit Section's Juniors** January 20.

A Proposed TRIP TO MARS would require a space ship approximately 248 ft high and 82 ft wide which would accommodate 8 men. Estimated complete cost would be about $626,000,000, according to Charles Villiers and Larry Bommarito of Boeing Airplane Co. who spoke at **Alberta Group** February 19.

SECRET OF SUCCESS of the Eaton Tandem Axle is in the method of lubrication: oil is centrifuged off the top helical gear into a collector tray at the top of the housing. From the tray the lubricant is fed through a gallery to the differential gears and falls down into the sump. The oil is kept cool by circulation and contributes greatly to increased wear life.

B. F. Bennett, district sales manager for Eaton Mfg. Co. spoke on the tandem axle at **Salt Lake City Group** on January 26.

ADDRESSING SAE'S ONTARIO SECTION on February 17, President Harry E. Chesebrough said: "No single automobile company could propose industry-wide standards for, say, a transmission fluid, a brake lining material, or anything else, without risking Government disapproval. But such standards coming from the SAE are welcome and authoritative. This is really a tremendous tribute to SAE members . . . a product of that individualism and integrity which I know you will always retain."

METROPOLITAN SECTION Chairman Robert W. Hogan (center) presents **Alfred P. Sloan, Jr.** (left) his 50-year certificate of SAE membership. (See SAE Journal, January issue, p. 122.) SAE Secretary and General Manager John A. C. Warner (right) participated in the ceremony held in Mr. Sloan's New York City suite on February 9.

A. D. McLean (left) of Kenworth Motor Truck Co. spoke at **Northwest Section** February 5 on simplified air suspension system for trucks and trailers. Co-authors of the talk are **G. R. Giberson** (center) and **R. F. Burris.**

SAE Section Meetings

BALTIMORE

May 12 . . . M. Christenson, president, Acer Racer Corp. "Go-Carts." Longley Restaurant, Towson, Md. Dinner 7:00 p.m. Meeting 8:00 p.m. Special Feature: Demonstration; Door Prizes.

BUFFALO

May 18 . . . 7th Annual SAE — SCCA Sports Car Meeting. Karl E. Ludvigsen, editor, Sports Cars Illustrated. "Engineering Grand Prix Cars." Buffalo Trap & Field Club. Concourse de Elegance of sports cars in 9 classes. Time 4:30 p.m. Dinner 7:00 p.m. Meeting 8:00 p.m. Trophies to be awarded for Class Winners and Best of Show.

CENTRAL ILLINOIS

May 16 . . . University of Illinois, Peoria. "Engineering Education in Russia." Dinner 6:30 p.m. Meeting 7:45 p.m.

CLEVELAND

May 9 . . . Jack L. Hooven, project engineer, Ford Motor Co. "Truck & Bus." Tour of Ford Lorain Plant 4:30 p.m. Dinner 6:15 p.m. Meeting 7:00 p.m.

FORT WAYNE

May 19 . . . Stanley M. Johnson, accounting supervisor, Indiana & Michigan Electric Co. "The Steam Automobile." Orchard Ridge Country Club, Lower Huntington Road, Fort Wayne. Dinner 7:30 p.m. Meeting 8:30 p.m. Special Feature: Ladies Night and display of Antique Cars.

INDIANA

May 18 . . . Dick McGeorge, public relations director, Champion Spark Plug Co. "Non Technical — Current Racing Items." Indianapolis Athletic Club, 350 N. Meridian St. Cocktails 6:30 p.m. Dinner 7:00 p.m. Meeting 8:00 p.m. Special Feature: Film of the 1959 "500" Race.

KANSAS CITY

May 19 . . . Field Trip. TWA Training Center. Guest Welcome. R. Keith Bldg., Kansas City

METROPOLITAN

April 28 . . . Hal J. Scheule, supervisor, Gasoline & TEL Group, Petroleum Labs., E. I. du Pont de Nemours & Co. "Carburetor Icing Test Methods." Roger Smith Hotel, Lexington Ave. & 47th St., New York City. Luncheon 12:00 noon. Price $3.00.
May 19 . . . John F. Creamer, Sr., president, Wheels, Inc. "Brake Drums." Roger Smith Hotel, Lexington Ave. & 47th St., New York City. Luncheon 12:00 noon. Price $3.00.
May 13 . . . Spring Social. Sleepy Hollow Country Club, Scarborough-on-Hudson, New York. Afternoon — golf, bridge, etc. Sponsored cocktail hour. Dinner-dance, $9.00 per person.

MID-MICHIGAN

May 12 . . . Golf Stag. Brookwood Golf Course, Flint, Michigan. Golf starts 9:30 a.m. Dinner 4:00 p.m.

NORTHERN CALIFORNIA

May 18 . . . A. Paul Mantz, Mantz Air Service. "Stunt Flying in Early Aircraft." Engineers' Club, 206 Sansome, San Francisco. Dinner 6:30 p.m. Meeting 8:00 p.m. Special Feature: Films of early aircraft.

NORTHWEST

May 13 . . . Annual social meeting & Ladies Night. Moonlight cruise & dinner-dance. The cruiser, "White Swan" on Lake Washington. Come aboard at 6:00 p.m. Special Feature: Introduction of new officers.

PITTSBURGH

May 18 . . . Dr. M. R. J. Wyllie, director of Reservoir Mechanics Division, Gulf Research & Development Co. "Sports Car Racing — Car Maintenance and Driving Technique." Wenango Country Club, Oil City. Dinner 6:00 p.m. Meeting 7:00 p.m.

ROCKFORD-BELOIT

May 9 . . . D. J. La Belle, truck engineer, GM Truck & Coach Division. "A New Concept in Light Weight Highway Tractor Design." Wagon Wheel Lodge, Rockton. Dinner 6:45 p.m. Meeting 8:00 p.m. Special Feature: Cocktail Hour sponsored by Gunite Foundries Corp. Coffee Speaker: Edward C. Fales, president, Gunite Foundries Corp.

WILLIAMSPORT

May 2 . . . Dr. George W. Minard, professor, Chemical Engineering, Bucknell University. "An Introduction to Nuclear Power." Williamsport Moose Auditorium, East Third St. Dinner 6:45 p.m. Meeting 8:00 p.m.

SAE National Meetings

- **April 5–8**
  National Aeronautic Meeting (including production forum and engineering display), Hotel Commodore, New York, N. Y.
- **June 5–10**
  Summer Meeting, Edgewater Beach Hotel, Chicago, Ill.
- **August 16–19**
  National West Coast Meeting, Jack Tar Hotel, San Francisco, Calif.
- **September 12–15**
  National Farm, Construction and Industrial Machinery Meeting (including production forum and engineering display), Milwaukee Auditorium, Milwaukee Wis.
- **October 10–14**
  National Aeronautic Meeting (including manufacturing forum and engineering display), The Ambassador, Los Angeles, Calif.
- **October 25–27**
  National Transportation Meeting, Hotel Leamington, Minneapolis, Minn.
- **October 31–November 2**
  National Powerplant Meeting, Hotel Cleveland, Cleveland, Ohio.
- **November 3–4**
  National Fuels and Lubricants Meeting, The Mayo, Tulsa, Okla.

Continued from p. 96

a means of evaluating laboratory engine tests.

Twenty-eight 1956 model commercial-type vehicles from a single manufacturer made up the test fleet of 15 6-cyl trucks, three V-8 sedans, three 6-cyl sedans, and seven V-8 sedans. All vehicles were equipped with standard transmissions.

The test program lasted 18 months during which time from 8,000 to 25,000 miles of operation per vehicle were accumulated. Oil drain periods for all vehicles were approximately 5,000 miles. In addition to this operational time, all taxis were subjected to extensive idling periods which totalled as much as two hours of idling for every hour of travel time.

Engine Cleanliness — was measured in terms of average ratings of over-all sludge. No significant differences were found for the three test oils in the V-8 taxi service and the six cylinder truck facility.

Rusting — was confined to valve lifter body and plunger and on the stems of exhaust valves, and was present irrespective of oils, engines, and type of operation.

Wear — No large differences between the oils were apparent.

Comparison of Engine Type — In taxi service, more sludge was formed in V-8 engines than in 6-cylinder engines. This could be influenced by operation as well as oil and fuel consumption. There were no large differences between engine types in the same type of service with regard to piston skirt varnish, oil ring filling, and oil screen filling.

Type of Operating Service — The widely accepted view that the type of operating service is extremely important in evaluating oil performance was substantiated.

CRC 338 contains 70 pages including photographs, charts, tables, and graphs.

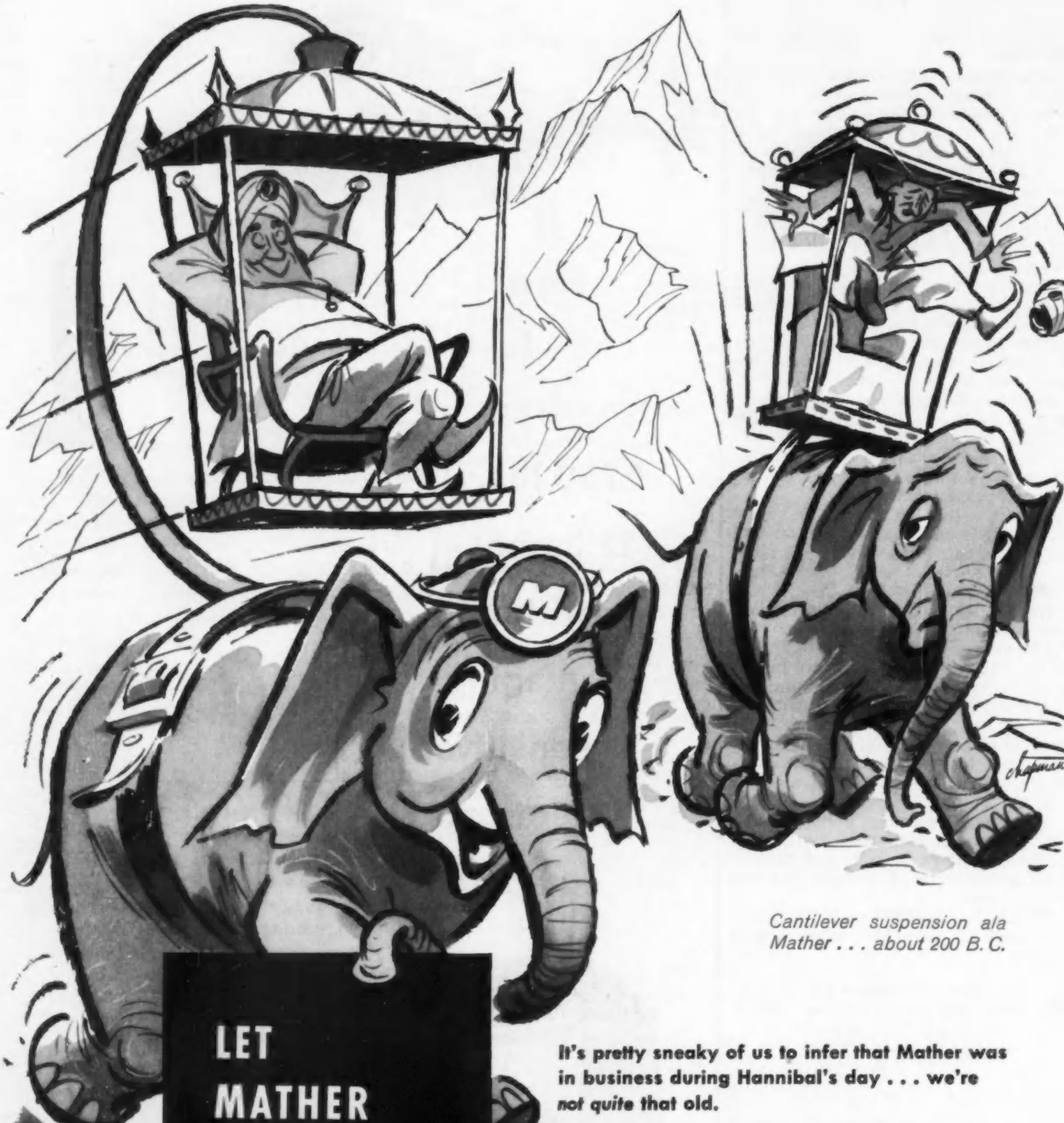
To Order CRC Report 338 . . . on which this article is based, see p. 6.

CRC Provides Lube Oil and Fuel Tests for Diesel Locomotives

THE techniques for conducting full-scale railroad diesel locomotive tests (given in CRC Report 339) will enable railroads to:

- Reduce the cost of testing lubricating oils and fuels for locomotive diesel engines.
- Improve the quality of such work.
- Provide a uniform system of communication which permits the work of testing agencies to be compared in

continued on p. 126



Cantilever suspension ala Mather . . . about 200 B. C.

LET MATHER SOLVE YOUR SUSPENSION PROBLEMS, TOO

It's pretty sneaky of us to infer that Mather was in business during Hannibal's day . . . we're *not quite* that old.

We're pioneers in suspension, though, and feel as old as Methuselah (experience-wise).

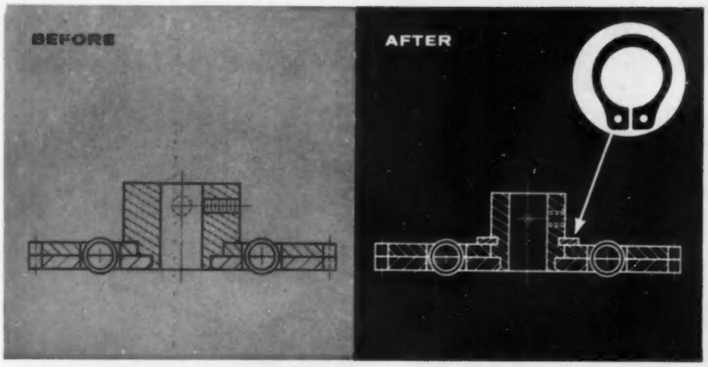
Maybe this and our research, design and manufacturing facilities can be helpful to you. We're "ready and willing, so just let us know".

MATHER

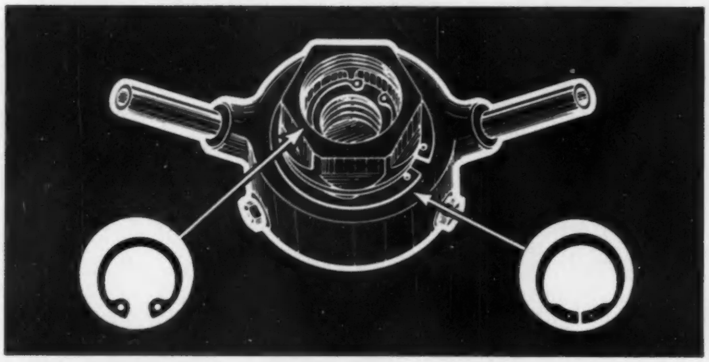
THE MATHER SPRING COMPANY

TOLEDO, OHIO

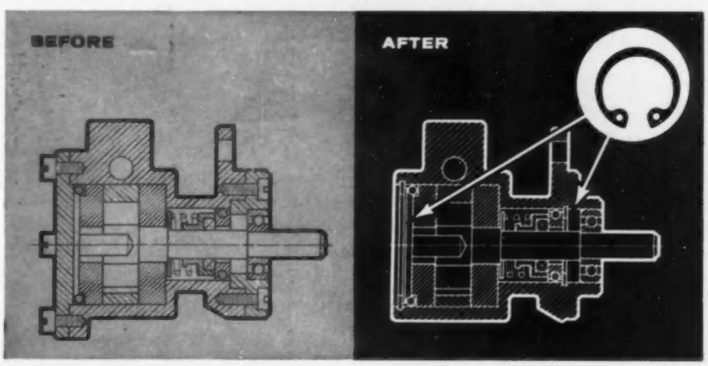

EVANS HEATERS ARE RIGHT
FOR TRUCKS BECAUSE
THEY'RE BUILT FOR TRUCKS!



Gear assembly improved. A Waldes Truarc Series 5100 retaining ring in this anti-backlash gear assembly eliminates machining and staking operations, reduces hub size, and allows easy disassembly, after gears are cut as a unit, for faster, better deburring. **Typical savings: $350.00 per 1000 units.**



Threaded retainers eliminated. In this self-sealing coupling, costly internal and external threaded retainers were eliminated by easy-to-apply internal (Series 5000) and external (Series 5108) Truarc retaining rings. **Savings per unit amounted to $4.02.**



End-cover design simplified. In this general-purpose pump, two Waldes Truarc, Series 5000, internal retaining rings make possible the elimination of two cover-plate castings (plus machining) and eight screws (plus drilling and tapping). Weight and dimensions are reduced and assembly and disassembly are greatly facilitated. **Typical cost savings: $1.48 per unit.**

Designing for axial assembly with Truarc retaining rings

eliminates parts, machining, speeds assembly, simplifies maintenance

The proper application of retaining rings on or in axial assemblies can often effect startling simplifications and economies in design when compared to corresponding designs with conventional fastening devices. A few typical examples, using basic types of retaining rings, are shown in the accompanying drawings.

Threading, tapping, drilling, facing and other costly, time-consuming operations can be eliminated. Retaining rings are already in wide use in a tremendous variety of equipment ranging from household products to high-precision military gear designed for use under the most severe environmental conditions. They are quickly and simply installed in easily cut grooves which can often be machined simultaneously with other operations. The rings can frequently replace bulkier, more costly fastening devices —such as nuts, screws, studs, threaded sleeves and retainers, cotter pins, set collars, rivets and machined shoulders.

What's more, rings frequently make practical designs which could be achieved with no other known fastening device.

Although the ring types shown here are basic, Truarc retaining rings come in 50 functionally different types, as many as 97 different sizes within a type, 6 metal specifications and 13 finishes. You'll find detailed descriptions of Truarc retaining rings and assembly tools, plus more than 70 typical applications in the new 24-page catalogue RR10-58. Write for your copy today.

And remember, Waldes engineers are always ready to help you solve your application problems—whether it involves one of the standard Truarc rings or a "special" to fit your particular requirements. Waldes Kohinoor, Inc., 47-16 Austel Place, Long Island City 1, N. Y. 9.1

WALDES TRUARC® RETAINING RINGS

Waldes Kohinoor Inc., Long Island City 1, N. Y.

TRUARC RETAINING RINGS . . . THE ENGINEERED FASTENING METHOD FOR REDUCING MATERIAL, MACHINING AND ASSEMBLY COSTS

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such a way that the sum total of that work comprises a coordinated system of applied research which will be of *real* value to American railroads.

By providing a uniform code for conducting tests and reporting results, tests conducted by one railroad may be interpreted by other railroads. Thus, the need for duplicate testing will be eliminated.

The data obtained from these techniques may be used to determine whether a given fuel-lubricant-engine combination possesses the characteristics which will enable it to meet the requirements of the railroads.

The service test technique and data forms included in CRC 339 are designed for the Electro-Motive Model 567 engine. However, the basic technique applies equally well to other types of railroad diesel engines or to the evaluation of experimental engine parts of new metallurgy or design.

To keep the report to a reasonable size, only one aspect of cooperative testing is covered in detail; namely, the evaluation of lubricating oils or fuel oils in locomotive diesel engines.

The report contains 73 pages which include 23 photographs.

To Order CRC Report 339 . . .
on which this article is based, see p. 6.

Factors Causing Shaft Seal Leakage

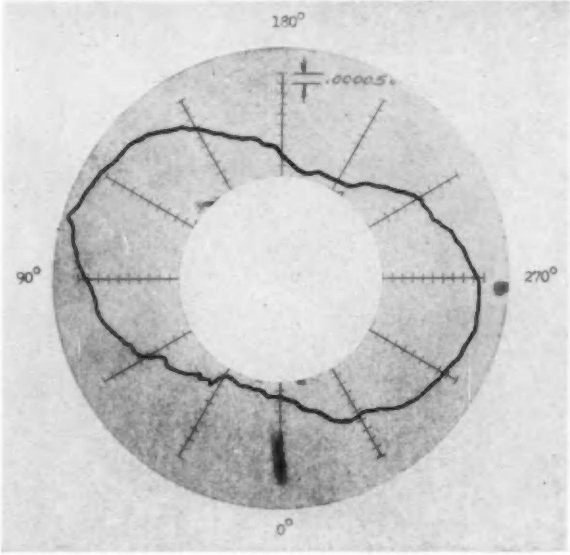

Fig. 1 — Talyrond trace of production shaft. A stiffening of seal lip material due to extreme cold or heat would cause seal failure on such an out-of-round shaft.

Based on paper by

ROBERT L. DEGA and JAMES D. SYMONS

General Motors Corp.

THERE are three equally important causes of seal leakage. They are the shaft, the assembly, and the seal itself.

A lip seal should be regarded as a precision-built assembly, similar in operation to a close fitting journal bearing. Therefore, some type of oil film must be sustained between mating surfaces. This film is on the order of 5–15 microin., depending on the seal lip loading.

Influence of the Shaft

The effects of shaft surface finish on the oil film can be as detrimental to operation as the physical characteristics of the seal itself. A too smooth finish will not support an oil film when the seal lip pressures are too high; a too rough finish will cause mechanical damage to the seal lip by abrasion and heat due to rubbing without lubrication. Carbonization of both seal lip and lubricant causes shaft wear, thereby providing a compatible surface at times. However, during this wear-in period, damage to the seal may be catastrophic.

Another effect of shaft surface finish is the increase in frictional torque with increased roughness. And coupled with surface finish may be the effects of shaft geometry.

Fig. 1 shows a typical Talyrond trace of a production seal. Here the ability of a seal to follow such a surface is in question. Various degree of out-of-round can be tolerated depending on such conditions as shaft speed, temperature, and viscosity of the sealant. At high shaft speeds, recovery properties of the seal lip may be slow enough to allow a standing gap to form. If cold or heat stiffened the lip material, the seal would fail on such a shaft but function perfectly on other more nearly round shafts. The camming action of the high points requires application of seals of relatively higher lip pressures. The resulting high loads due to inertia effects on the lip cause lubricant breakdown and associated high wear. Shaft run-out has the same affect as out-of-round and the degree which can be tolerated also is a function of shaft speed, temperature, and sealant viscosity.

Effect of Machining Lead

Machining lead in a shaft surface can cause seal leakage by mechanical transfer of the liquid under the seal lip. Considerable lead can be tolerated, provided the surface finish is fine enough to retain the sealant by a wiping action of the lip. Leakage depends upon the direction of shaft rotation. If the shaft is rotated in one direction the sealant will be scooped into the groove and carried under the lip seal. When the shaft is reversed the helical grooves impart an axial component to the sealant away from the lip and the seal will not leak. Shafts with uncontrolled leads and surface finishes require high lip pressure seals to machine the shaft during run-in.

Various uncontrolled conditions during assembly which result in nicks, scratches, burrs, and the like, are primary reasons for the failure of applications. They have to be controlled before corrective measures can be applied to quality control of seals.

Seal Variables

Production variables such as lip diameter, lip pressure, and eccentricity are the third primary cause for the leakage of seals immediately or shortly after being put into service.

Compatible diameters for a seal in a given application will be determined by the seal design, type of rubber compound, and shaft surface finish, so that each must be evaluated separately. In short, diameters compatible for one

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seal cannot be applied to another seal design, manufactured for the same application. It is fact that a smooth shaft, 5 microin., will require much closer selection of seal diameters than the same shaft finished to 15 microin. Field experience shows that two identical production seal applications having different surface finishes, require a seal lip diameter range of 0.030 in. for the 5–8-microin. shaft and 0.050 in. for the 15–18 microin. shaft.

Seal lip pressure designates the radial force exerted by the lip on the shaft as a result of trim interference, rubber hardness, section uniformity, eccentricity, and spring quality. Any one of these variables can cause a seal to malfunction.

In numerous applications where the sealed shaft is not properly surface finished, seals have been applied with extreme lip pressures to do the job of machining. This is a highly unsatisfactory practice. With proper control of lip pressure, lip diameter, and shaft finish, a seal can be made to operate like a precision fitted bearing and have no apparent contact with the shaft.

Rubber hardness contributes to lip pressure effects as well as to the stability of the seal section, hence its control in production is important. A range of rubber hardness from 69–84 Shore A affects the operating temperature of the seal rubbing face tremendously. Tests show that seals with low hardness deformed sufficiently under load to contact the shaft in a wide path adequate to build up a hydrodynamic film of lubricant. This film creates an opposing pressure head to counteract lip pressures and reduce material contract, with consequent lower temperatures. Seals having high hardness and narrow wear paths cannot support this type of film under high loads, hence the existing film is broken to cause material rubbing and high temperatures.

Seal Lip Eccentricity

Eccentricity of the seal lip in respect to its case is extremely important in its effect on lip pressure. For instance, a 2-in. diameter seal will show a change in its lip pressure of 1 psi when placed eccentric 0.005 in. Eccentricity can be caused by element displacement in a mechanically built-up assembly, section change due to poor mold register, and the trim operation. It is perhaps responsible for most failures occurring in testing, since the effect is not recognized when assembling the seal in a test fixture which has built-in eccentricity.

To Order Paper No. 130B . . .
on which this article is based, see p. 6.

Hot Rodding IS Very Close to Detroit

Excerpts from talk by

ROGER HUNTINGTON
Automotive Technical Writer
(Presented before SAE Detroit Section)

THERE are many instances where Detroit engineers have copied hop-up ideas from the rodders. (Not to imply, of course, that the *principles* hadn't been known for 50 years.) Cadillac tore a leaf from the rodder's book when they went to dual exhaust lines in '52. Buick's scavenger-type exhaust manifolds in '56 were an attempt to duplicate the efficiency of hand-fabricated tubular "headers" with a simple casting. Olds engineers started the "displacement race" in '54 when they increased the bore of the basic Rocket block ⅛ in.; hot rodders had been boring blocks and "stroking" crankshafts for years. (I don't know anybody who has outdone Pontiac, though, in going from 287 cu in. to 389 on the same basic tooling!) The peculiar form of madness known as "multiple carburetion"

continued on p. 131

Fig. 1 — Competition in the "gas coupe/sedan" division means cars with full body and upholstery, licensed for street operation. 1933 Willys coupe in foreground weighs 2250 lb. It is powered by supercharged, fuel-injected 1959 Cadillac engine developing 525 hp at 5500 rpm. Car has hit 132 mph at quarter-mile point, with elapsed times under 12 sec. Car on far side is Model A Ford coupe with supercharged Olds engine.

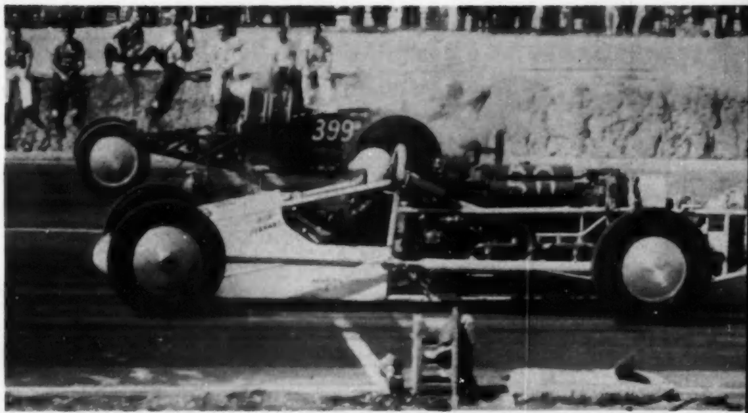

Fig. 2 — Aircraft engine competes with twin Chevrolets! In foreground: 4-wheel-drive dragster with aircooled V-12 supercharged Ranger aircraft engine of 600 hp. Tank clutch is behind. On far side: 2100-lb dragster with two supercharged Chevrolet V-8 engines totaling 500 hp. This twin Chev won, hitting 152 mph at end of standing quarter-mile!

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started in the hot rod field, and was taken up by Detroit as a weapon in the horsepower race. Hudson used dual carbs on the Hornet in '54; Chrysler used twin four-barrels on their big "300" model in '55; in '57 Olds and Pontiac went hogwild with *three* two-throats on their V-8's! (Incidentally, Detroit is in the process of getting the last laugh on this one. It is becoming painfully evident that *one* big four-barrel carb can do everything two or there carbs can do, and with a lot less cost, fuss, and bother!) And the ultimate in efficient fuel feed — constant-flow fuel injection into the port — was first developed by a young California hot rodder named Stuart Hilborn, back in 1948. He eventually formed a company to manufacture the systems for all types of racing engines, where they have since become just about standard equipment. Hilborn proved the impossible would work — so we find Chevrolet bringing out constant-flow fuel injection for their '57 models. The old hot rod trick of using bigger ports and valves has become a Detroit standard. An early example was on the '52 Olds engine.

It's interesting to speculate on the influence of customized cars on Detroit styling. I know a lot of gimmicks from the custom field that were later seen on stock cars. The "Frenched," or visored, headlight — where the body sheet metal is brought out to shroud the light — was first seen on some of the '55 models. A favorite customizing trick is to *remove* chrome trim from the body. Who cay say Olds didn't remove a flock of chrome on their '59 models — and who can say they didn't have an unreasonable amount to work on on the '58's? The long, low look has always been desired by the customizer. He will go to great lengths — chop sections out of the roof posts, or even out of body side panels — to get the lower look. Detroit has faced similar problems; in fact, I understand reducing body height, while still retaining adequate interior space, is one of the toughest engineering problems in the Motor City these days. Certainly, outstanding early examples of the art would be the '53 Studebaker coupes, '56 Cadillac Eldorado Brougham, '57 Plymouth Fury. The '53 Stude is also remembered for a *de*-emphasized grille, which is a favorite method of the customizer. Elaborate two-tone color schemes — more than just a light top and dark bottom — have been used for years on customs. Olds introduced the theme to the industry in 1954.

I could go on and on . . . but I think you get the idea. The hot rod sport *has* had an important impact on Detroit engineering and styling in the last 10 years. And I think the influence will continue for years to come.

Figs. 1 and 2 show some interesting examples of the hot rodder's art.

Petroleum to Continue as Prime Fuel for Aircraft

Excerpts from paper by

W. S. MOUNT
Mobile Oil Co.

PETROLEUM FUELS are doing well in today's aircraft . . . and can be expected to continue as the prime energy source for aircraft in the foreseeable future.

In spite of record demands for additional fuel for commercial and military jet aircraft, petroleum suppliers in the past have accommodated their refinery operations rapidly to meet the new demands. Now, with continued gains in military demands, aircraft requirements are suddenly accelerating. The new volume requirements appear to be causing no diffi-

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PROPERTIES OF "DELRIN"

Property	Data	INTERIOR HARDWARE (Door Handles, Window Cranks)	BUSHINGS & BEARINGS (Suspension Systems & Steering Linkages & Door Hinges)	SQUIRREL CAGE BLOWERS (for Heaters & Air Conditioners)	GEARS	MECHANICAL CABLE CASINGS (Push-Pull & Rotary)	INSTRUMENT HOUSINGS	WINDSHIELD WIPER (Pivots or Transmission Housings)	FUEL SYSTEMS (Pump and Carburetor Parts)	ELECTRICAL COMPONENTS (Bulb Sockets, Switch Housings & Toggles)
Tensile Strength	(ASTM D638): 10,000 psi at 73°F. 4,000 psi at 250°F.	✓	✓	✓	✓	✓	✓	✓	✓	✓
Stiffness	(ASTM D790): 410,000 psi at 73°F. 90,000 psi. at 250°F.	✓	✓	✓	✓	✓	✓	✓	✓	✓
Dimensional Stability: Load	0.5% Def. under 2,000 psi load at 122°F. (ASTM D621) 338°F. Heat Dist. Temp. at 66 psi (ASTM D648)		✓	✓	✓	✓	✓	✓	✓	✓
Dimensional Stability: Creep Resistance	0.4% Deformation at 113°F. and 10,000 hrs. under 500 psi load		✓	✓	✓		✓	✓	✓	✓
Dimensional Stability: Environmental	Linear Change +0.1% going from 0 to 50% RH +0.4% going from 0% RH to Saturation +0.1% in gasoline		✓		✓	✓	✓	✓	✓	✓
Solvent Resistance	Weight Change +0.3% in Gasoline at 73°F. +0.9% in Brake Fluid at 158°F. —0.2% in "Unifio" at 158°F. +1.9% in Ethanol at 122°F. 0.0% in Kerosene at 140°F.		✓		✓	✓		✓	✓	✓
Toughness	Fatigue Endurance: 5,000 psi at 73°F. Impact (Izod— ASTM D256) 1.2ft.lbs./in.at—40°F. 1.4ft.lbs./in. at 250°F.	✓	✓	✓	✓	✓	✓	✓	✓	✓
Bearing Properties	No Slip Stick No Squeak Coeff. of Friction on steel 0.2 ± 0.1 Dry 0.08 Lubricated	✓	✓			✓	✓	✓	✓	✓
Excellent Appearance	Colorability High Gloss Paintability	✓					✓		✓	✓
Serviceability	Wear Resistance Mar Resistance Stain Resistance Corrosion Resistance	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fabricability	Injection Molding Extrusion Machining	✓	✓	✓	✓	✓	✓	✓	✓	✓
Electrical Properties	(ASTM D150): Dielectric Constant: 3.7 Dissipation Factor: .004 at 73°F. from 10^2 to 10^5 cps						✓		✓	✓

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culty, and commercial jet aircraft are getting off to a good start.

Industry-wide standardized jet fuel seems unlikely. Instead, individual airplanes will probably become more and more exacting in the jet fuel requirements for their particular aircraft and operations.

In the military picture, JP-4 should soon be improved in quality. It will remain as the single very large volume military jet fuel, with limited growth beyond 1965.

New requirements for manned aircraft will probably develop around highly specialized products of smaller volume for the very high performance machines.

The wide-cut ASTM Type B (designated JP-4 by the military) has real performance possibilities for commercial aircraft, and in this field there is also adequate room for quality improvement. Its possibilities for airline consumption in certain geographical areas should be carefully considered by the airlines.

The oil industry has retained, even improved on, its ability to meet the demands resulting from the new transportation developments. Somewhat in the same fashion that it handled the added burden resulting from high-compression passenger cars, high-octane aviation gasoline, conversion of railroads from coal to diesel, it is now meeting fully the needs of jet aircraft. Adequate and economical fuel should be a real stimulus to further development of high-speed transportation.

Economic availability of petroleum fuels, along with the considerable room for better quality, gives petroleum a definite margin over chemical fuels and nuclear power in the manned-aircraft category. While non-petroleum fuels will undoubtedly find application in rather specialized fields, the great bulk of air transportation will remain for many years under petroleum power.

To Order Paper No. 114A . . . on which this article is based, see p. 6.

Wanted: Additives To Gang up on Wear

Based on paper by

M. L. KALINOWSKI and R. A. NEJDL

Standard Oil Co. (Indiana)

(Presented before SAE Baltimore Section)

WHAT the cold engine needs to reduce wear at startup is additives in fuel and lubricant which work better together.

Tests of additives carried out by starting engines at 60–70 F and 2- and 18-hr shutdown periods, with intake-air humidity of about 50 grains revealed the following about their ef-

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fectiveness: In fuel, light mineral oil and phosphate esters offer no protection against startup wear. Sulfonates, which are excellent antirusts in some applications, are also ineffective. After a 2-hr shutdown, a polymeric C_{18} fatty acid mixture reduces wear 20% and an amine salt is twice as effective. But neither reduces wear after an 18-hr shutdown. Amine dialkyl phosphate performs best. It reduces wear 40% after both shutdown periods.

Effectiveness in Lube Oil

No protection against wear is gained by putting sulfonate antirusts, zinc dialkyl dithiophosphate inhibitor-antiwear compound, or polyisobutylene V.I. improver in the lubricant. The commonly used types of detergent — barium organo-phosphorus salt and barium sulfonate-phenate — do give some benefit after the 2-hr shutdown period. No greater reduction in wear is obtained for a complete 10W-30 oil containing either one of the detergents, together with an antirust, an inhibitor-antiwear, and a V.I. improver.

When an engine was run on the most effective combination of additives in the fuel and the oil — amine dialkyl phosphate and barium organo-phosphorus salt — they were found not to to reinforce each other, but to reduce wear to the extent achieved with the antirust alone.

To Order Paper No. S234 . . . on which this article is based, see p. 6.

Business Flying Zooms Past Airlines

Based on paper by

HENRY W. BOGGESS

Sinclair Refining Co.

AMERICAN industry is responsible for the greatest growth in production and use of fixed-wing aircraft in the past decade. Last year it operated about 27,000 airplanes as compared with the scheduled domestic carriers' 1800 and it accumulates 23 million miles per year against the airlines 16 million.

Business men use the scheduled airlines, but those lines touch less than 600 of the 6000 airports in the country. To solve time and distance problems in many areas, the company-owned airplane came into use as a supplementary tool. Now it has become a transport system in its own right.

New Problems for Business

When a company decides it needs an airplane, the first problem it faces is acquisition. Before making a move, it should analyze its needs to insure proper consideration of safety, range, load limitation, capital outlays, as well as fixed and operational costs.

The second problem is one of maintenance. Maintenance must be planned. It is comparatively easy if each pilot and copilot from the chief pilot on down is a graduate FAA certified airframe and powerplant mechanic. The airplane, its engine and all components will be in better day-by-day condition, downtime will be minimized, scheduled flights will have fewer delays and cancellations, and the operation will be safer and less expensive.

Efficient utilization is essential and to this end there should be a central scheduling point to see that needs are fully met and to lessen trips with empty seats.

The operation of company airplanes requires centralization of responsibility and a definite organization. Most fleet owners have an aviation department wherein authority and duties are pinpointed. It must be staffed with qualified people from the top down, and such people are hard to find. There are not enough of them. The small company has to rely on training schools to get the needed manpower; the big companies, operating many airplanes, sometimes train their own personnel and promote from within the ranks.

The myriad responsibilities resting

continued on p. 141

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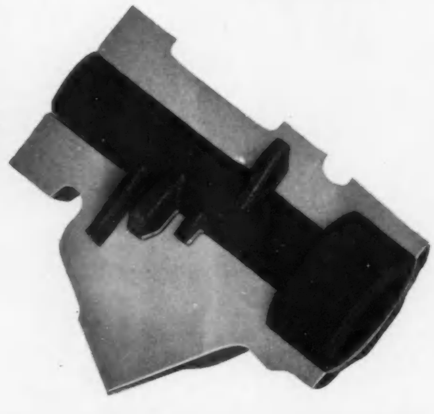

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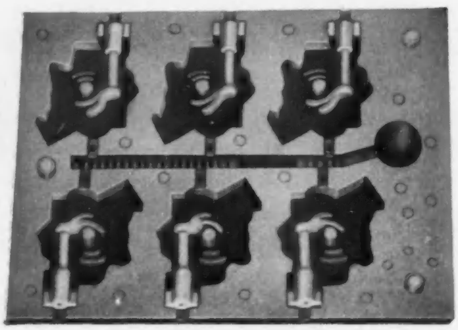

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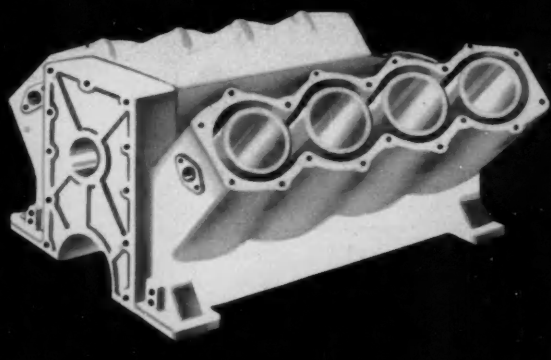

How Aluminum Engines

cut weight, improve performance, reduce manufacturing costs

TURN PAGE FOR INFORMATION

ALUMINUM ENGINES

in two 1960 automobiles—one a compact U. S. car, one a luxury English car—are this year's biggest automobile news. The difference between these two cars—in design, in size, in motoring features, in price—is great. Yet the fact that *both of them are powered with aluminum engines* proves automobile experts agree that the greatest enemy to efficiency is weight. And the new aluminum engines are a big step in automobile weight reduction.

Reduced Weight—Better Performance

The aluminum engine block can save as much as 75% of the weight required by the old cast iron blocks. This weight saving, plus the resulting savings in chassis, cooling system and other parts, can reduce dead weight by as much as 450—500 pounds per car. With this much less dead weight to haul, aluminum-engined cars will deliver better gasoline mileage, will accelerate faster, stop quicker, ride better. There'll be less wear on brakes and tires, more responsive handling, better control.

Lower Manufacturing Costs

Automotive engineers agree that aluminum engines will cost less to produce than cast-iron engines, even though the per-pound basic material cost of aluminum is higher. One big reason: there is about three times more metal in a pound of aluminum than in a pound of iron. Six V-8 engine blocks can be cast from a ton of iron—and nearly sixteen from a ton of aluminum. And, lightening of the chassis permitted with aluminum engines will also help cut production costs.

Savings in shipping costs are substantial, too. It costs much less to ship aluminum engines than it does to ship iron engines.

Aluminum's workability and light weight also reduces machining and finishing and assembling costs far

below those for iron and steel. Aluminum is ideally suited to automation and other cost-cutting production techniques.

Aluminum Engines and Automotive Engineers

One of the most intriguing aspects to automotive engineers currently working on aluminum engines is the opportunity aluminum provides to design *out* established concepts. The engine itself may be shaped much the same as a conventional iron engine or it may be in a pancake or other shape. It may be designed for liquid-cooling or air-cooling. It may be designed for front mounting or rear mounting. And as cylinder head and block designs develop, there also develops a chain of new design concepts in drive line and chassis areas.

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Reynolds Aluminum

the metal for *automation*

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continued from p. 136

on an industrial aviation department are similar to those borne by the scheduled airlines except that public relations and sales are not involved.

To Order Paper No. 136A . . .
on which this article is based, see p. 6.

Small Gas Turbines Prefer Certain Fuels

Based on paper by

M. J. BOEGEL and
J. F. WAGNER
Gulf Research & Development Co.

THE gas turbine engine is much less critical of fuel properties than the piston engine nevertheless fuels vary in their effect on combustion cleanliness.

Fuels ranging from gasoline to No. 2 fuel oil were tested for combustor deposition and exhaust smoke at three levels of operating severity in a Boeing 502-10C gas turbine engine. Operation was unsatisfactory with the ASTM No. 2 fuel oils, many No. 2-D diesel fuels and even with some No. 1-D diesel fuels, due to deposits breaking loose from the combustors and wedging in the turbine nozzles. Such deposits can result in immediate engine malfunction in the form of power loss, or surging, or both during acceleration, and cause high exhaust gas temperatures at light-duty operation. The long-term effect can be blade damage.

Effect of Deposition Rates

The tolerance of the engine for combustor deposits decreased as operating severity increased. With light duty, fuels having combustor deposition rates in excess of 5 g per hr resulted in unsatisfactory operation; with heavy-duty procedure and at continuous maximum-power operation, fuels having rates in excess of about 1 g per hr resulted in unsatisfactory operation (Table 1).

On the basis of relatively few data, fuels performing well under light-duty conditions also did well under heavy-duty operation. Fuels giving unsatisfactory performance did so with both light and heavy-duty operation. Exhaust smoke was usually heavies with fuels giving heaviest combustor deposits.

Correlation studies showed that combustor deposition tendencies of good and poor fuels could be predicted reasonably well from several fuel properties and empirical factors. Naphthalenes and hydro-carbon ratio were among the best correlating factors for both light- and heavy-duty procedures.

Effects of Additives

In a single test with leaded gasoline (48% cracked, 49% platformate,

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Table 1 — Comparison of Combustor Deposition Rates in Boeing 502-10C Turbine With Light- and Heavy-Duty Cycling

Fuel	Light-Duty Cycle		Heavy-Duty Cycle	
	Average Combustor Deposition Rate, g/hr	Shedding of Combustor Deposits	Average Combustor Deposition Rate, g/hr	Shedding of Combustor Deposits
Automotive gasoline, clear	1.6	No	0.1	No
ASTM No. 1-D 100% straight run	2.3	No	0.3	No
Kerosene	0.8	No	0.35	No
ASTM No. 2-D 100% straight run	6.6	No	1.3	Yes
ASTM No. 1-D, 70% cracked	5.5	Yes	5.3	Yes
ASTM No. 2 fuel oil, 100% cracked	16.8	Yes	22.5	Yes

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3% butane) the total weight of carbon and lead compounds in the combustors was about 40% lower than that obtained with the clear fuel. The concentration of tel was 0.144% by weight.

To Order Paper No. 114C . . . on which this article is based, see p. 6.

CRC Analyses 1958 Road Rating Exchange Data

THE 1958 CRC Road Rating Program consisted of two parts. One was set up to study vehicle rating characteristics at various throttle positions using fuels with different sensitivity and hydrocarbon content. The other was an optional investigation of rumble ratings of selected fuels in high requirement engines. The results of both parts of this program are contained in CRC Report 340, "Analysis of the 1958 Road Rating Exchange Data."

In Part 1, Modified Uniontown and Modified Borderline road octane numbers were determined for six test gasolines. These ratings were made by 22 participating laboratories using 26 test vehicles of six different makes. Ratings were made at maximum throttle opening and, where possible, at throttle positions corresponding to 6, 8, 10, 12, and 14 in. of mercury manifold vacuum.

Based on these road test results, average ratings have been determined for the test fuels. These average ratings have been inspected for precision, and have been examined with respect to the influence of laboratory properties on road antiknock performance. The six test fuels were:

Three fuels used in the 1957 program:
RMFD-80-57, RMFD-81-57, and RMFD-83-57.

Two commercial fuels:
RMFD-96-58 and RMFD 97-58.

A 99 Research octane number full-boiling range reference fuel:
Blend 11-C-58.

Rumble ratings of selected fuels in high requirement engines comprised Part 2 of this program which was conducted in the hope that some insight into the problem of rating fuels for rumble would be gained. No specific test schedule was outlined for the rumble studies . . . and insufficient data were obtained to make a comprehensive analysis. However, all data submitted on rumble are included in full in CRC 340.

Repeatability of the road ratings obtained during the 1958 program was less precise than in past years. Reproducibility, on the other hand, compared favorably with past experience. Only maximum throttle data from the

continued on p. 144

Table 1 — Repeatability and Reproducibility Values

Repeatability	Modified Uniontown	Modified Borderline	Laboratory Research
1952	0.63	0.84[a]	0.26
1953	0.49	0.43[a]	0.14
1954	0.62	0.47[a]	0.23
1957	0.48	0.53[b]	—
1958	1.04	0.76[b]	—
Reproducibility			
1952	1.38	1.34[a]	0.29
1953	1.56	1.76[a]	0.39
1954	1.41	1.05[a]	0.43
1957	1.18	1.18[b]	0.32
1958	1.22	1.01[b]	0.41

[a]Moderate engine speeds
[b]2000 engine rpm

continued from p. 143

1958 program, of course, has been included in these comparisons. Values of repeatability and reproducibility are compared to those of past programs in Table 1. Values are expressed as standard deviations in octane number unity.

The precision of Modified Uniontown ratings was generally best at maximum throttle opening, and the precision of Modified Borderline ratings was generally best at maximum throttle opening and at low engine speeds.

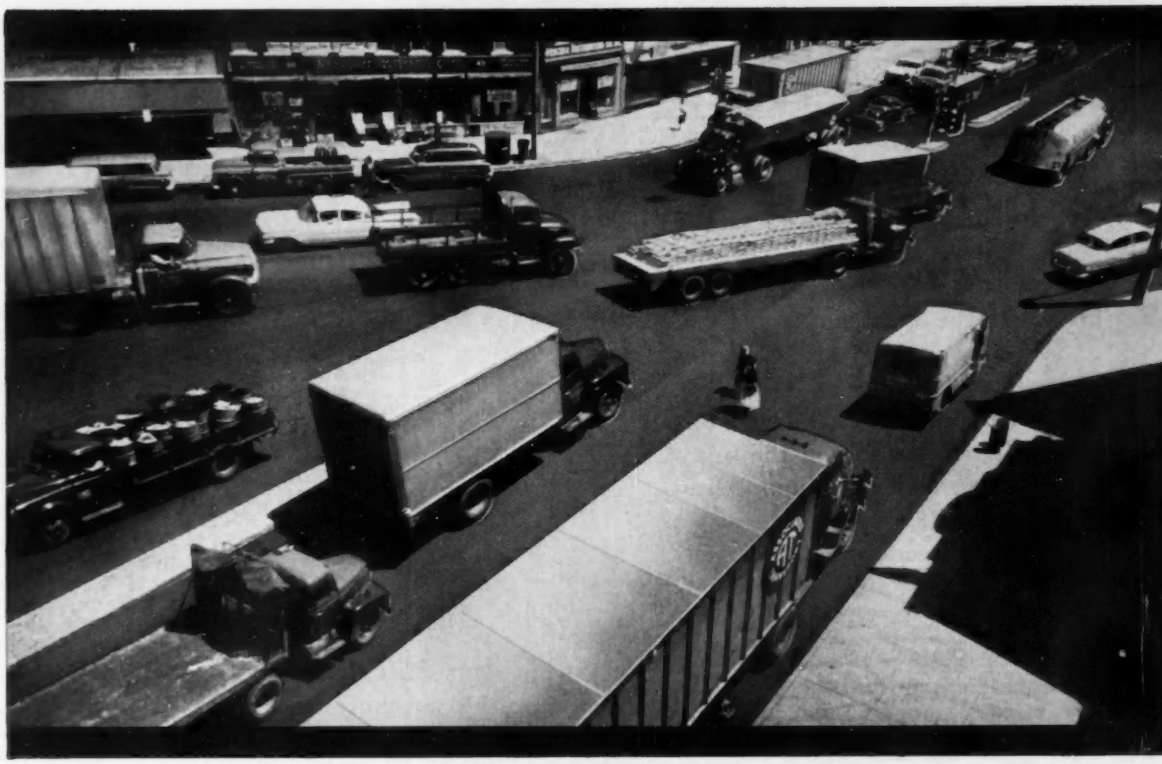
The 1957 fuels, RMFD-80-57, RMFD-81-57, and RMFD-83-57, were also rated in the 1958 program. The laboratory and road ratings of these fuels obtained in 1957 were repeated very closely in 1958. Laboratory and Modified Uniontown average ratings differed by no more than 0.2 octane number in the two years, and the maximum difference in Modified Borderline average values was 0.8 octane number.

Modified Borderline fuel ratings decreased with increasing engine speed and manifold vacuum. (The depreciation of all fuels tested was greatest at high engine speed and at part throttle.) Furthermore, increased fuel sensitivity increased depreciation at all engine speed and throttle opening combinations. This effect of sensitivity on depreciation increased as engine speed and manifold vacuum increased. The effect of olefins on depreciation is similar to that of sensitivity for this sample of fuels, but the individual contribution of each can not be defined because of intercorrelation between hydrocarbon composition and sensitivity in this sample of gasolines.

Although fuel ratings decrease at high engine speeds and at part throttle, engine octane number requirements also decrease at these conditions. In general, critical knocking areas are at maximum throttle and at throttle openings corresponding to manifold vacuums above 10 inches of mercury. The noncriticality of the region between maximum throttle and 10 inches of mercury is probably due to rich fuel-air mixtures and distributor vacuum advance characteristics.

Only limited rumble data were reported for this program option. These limited test results showed that it was possible to determine rumble requirements of engines in terms of the leaded isooctane-leaded benzene (LIB) reference fuel system. It was also indicated that test fuels could be rated for rumble tendency using the LIB fuels, although such ratings may be qualitative only. The LIB reference fuels did not bracket the rumble requirements of all cars . . . rumble occurred on LIB-100 (isooctane plus three cubic centimeters of tetraethyllead per gallon) after deposit accumulation in engines with higher than standard compression ratios.

To Order CRC Report 340 . . .
on which this article is based, see p. 6.



Plastics Potentials For Unlubricated Bearings

Based on paper by

R. E. HARMON

U. S. Gasket Co.

PLASTICS are getting widespread attention these days as potential materials for unlubricated bearings. Polytetrafluoroethylene, the fluorinated version of polyethylene, is the outstanding candidate, when properly reinforced or treated — to be designed into many greaseless automotive bearing applications. More commonly known as Teflon TFE fluorocarbon resin, it combines high-temperature resistance and low coefficient of friction.

In the development production stage at the present time, but also to be considered for such applications, are Teflon FEP fluorocarbon and Delrin acetal resins, which are tough and wear-resistant plastics. Nylon is also to be considered. All of these plastics are difficult to adhere to other substances when adhesion is desirable . . . and this antistick quality is of prime importance in a bearing for dry or unlubricated applications.

Also, all of these plastics are oil and grease-resistant and are used with lubricants in many areas. They will operate, however, with acceptably low wear and friction in the absence of any lubricant.

The nylon and TFE fluorocarbon resins have been applied for some years in a number of dry applications with limited success with steels and other metals being used as the mating surface. Delrin acetal resin and Teflon FEP fluorocarbon resins have been applied experimentally as bearings.

These plastics vary widely in frictional and wear characteristics as well as in costs. However, in their natural bulk form (over 0.030 in. in thickness), they are limited by several of their physical properties. Particularly are they limited by their (1) high thermal expansion, (2) poor heat conductivity, and (3) low compressive strength or load-carrying capacity. It is to be expected, nevertheless, that plastic materials will be designed either reducing the importance or taking advantage of these apparently disadvantageous physical properties.

Currently, plastic dry bearings fall essentially into the following types: (1) unmodified or natural state types; (2) filled mixtures; (3) impregnated into wire screen or perforated metal with or without attached metal backing or laminates of filled compositions to metal; (4) woven fabric, usually adhered by adhesives to metal or other plastic backings; (5) impregnated porous bronze with metal backings.

The future may well see improvements in these types and additions of other types.

To Order Paper No. 122B . . . on which this article is based, see p. 6.


ECONOSEAT

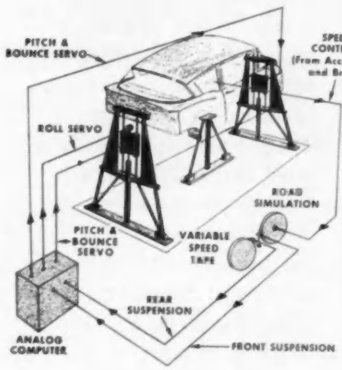
New Simulator Is Aid To Better Ride Analysis

Based on paper by

ROBERT H. KOHR
GM Research Laboratories

THE RIDE SIMULATOR, which involves three complex components, is a system for analyzing automobile ride by utilizing the most modern methods and equipment. It is a servocontrolled motion simulator, which is composed of:

1. A tape recorder to provide road wave inputs into the system. (The signal on the tape is picked off at two points simulating the front and rear



New Ride Simulator

wheels of a car. The tape speed is variable and, by speeding up the tape, the car being simulated is also "speeded up.")

2. An analog computer, which takes in the signals from the tape recorder and, from these inputs to the car's suspension, determines what car body motions would result. (The analog computer runs on "real time"—which means that the ride responses that are generated by the computer occur at the same rate as would the equivalent ride response of a real car on a real road.)

3. A motion simulator to reproduce the car body motions determined by the computer. (The simulator is comprised of a portion of a standard car body and is driven by electrohydraulic servomechanisms whose inputs are output voltages from the analog computer. . . . Two passengers may be accommodated in the motion simulator and the driver may control the speed of the car by pressing the brake or accelerator—which sends a signal to a small computer. The computer determines the resulting car speed . . . and then sends a speed signal to the tape recorder.

This Ride Simulator, the functioning of which is detailed in SAE Paper No. 144A, has demonstrated its ability to

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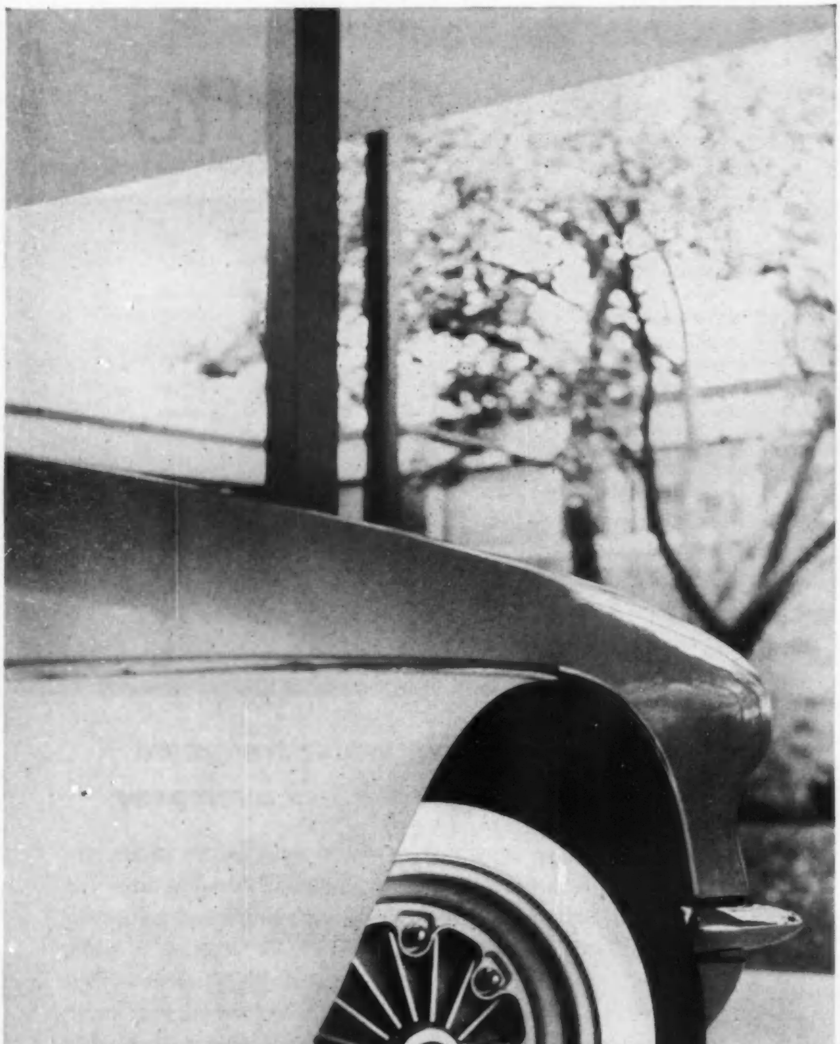

continued from p. 149

reproduce the on-the-road ride response of real cars.

The way is now open to evaluate new suspension systems without recourse to expensive component constructions . . . and to study the passenger and seat combination under closely controlled conditions.

The Ride Simulator is an important step forward in ride analysis because it will enable improvements in ride to be made with a minimum of time and effort.

To Order Paper No. 144A . . .
on which this article is based, see p. 6.

Zinc Additive Oils Mar High-Load Diesels

Based on paper by

J. R. BELT and L. G. SCHNEIDER

USN Engineering Experiment Station

ZINC-BEARING oil additives may be torpedoed for highly loaded Navy diesels. There is evidence that their presence adversely affects lubrication of piston pins and bushings.

Several experiences have served to spotlight problems with zinc additives. The first occurred with a slightly modified 2-stroke, V-type submarine diesel, turbocharged to determine the possibilities of increasing horsepower. A majority of rod bushings were severely wiped and some almost disappeared. Suspecting that the trouble might be caused by the zinc di-alkyl dithiophosphates in the oil, tests were run with a nonzinc oil and the severity of the wiping was reduced in spite of longer periods of operation with heavier loads.

The second experience was with an 8-cyl, 1400-hp, nonmagnetic turbocharged engine. Using a qualified MIL-L-9000D symbol 9250 oil, there was gross failure of one piston pin floating bushing after 360 hr of cyclic operation, and more bushing failures after about 100 hr additional. Very similar results were obtained with another zinc-bearing oil on a second run. On a third run, with a nonzinc oil, all bushings were excellent after 96 hr.

What Experience Tells

1. Navy diesel lube oils differ in their ability to lubricate heavily loaded piston pins and bushings.
2. Some present and near-future engines of interest to the Navy can be operated at piston pin loadings in the zone where these oil differences are significant.
3. This zone, lying between adequacy and inadequacy, is a narrow one.
4. The offending additives, used in many diesel oils, are useful in inhibiting

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oil oxidation and bearing corrosion. Experience does not reveal how the additives work to affect load-carrying ability of the oil in the piston pin area. (The opinions expressed are the authors and are not to be construed as official or reflecting the views of the Navy Department or Naval services at large.)

To Order Paper No. 110A . . .
on which this article is based, see p. 6.

Noble Gas Plasma Diode Studied for Direct Conversion

Excerpts from paper by

FRANK E. JAMERSON
Research Laboratories, GMC

THE direct conversion of nuclear fission heat to electricity in a plasma diode that utilizes a new mode of plasma generation is being studied. Fission fragments from a uranium-bearing cathode are used to produce a plasma of relatively low fractional ionization in a noble gas (Fig. 1).

Electron mobility in a noble gas is sufficiently high to provide a diode re-

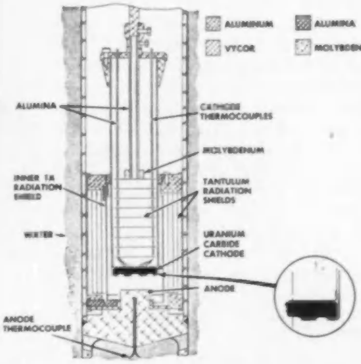

Fig. 1 — Noble gas plasma diode in reactor test chamber.

sistance that could be sufficiently low to operate efficiently. The inherent advantage of such a diode converter is that it eliminates the use of an alkali metal in the diode.

An experiment has been performed in the University of Michigan research reactor in which a uranium carbide cathode was operated up to temperatures of 2000 K. The results of this experiment indicate the following:

1. Thermoelectric power description of a plasma diode configuration is not valid for a system of low (10^{-5}–10^{-8}) fractional ionization.
2. The present diode geometry affected the electron current distribution.
3. If all the current were assumed

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to come from UC, then the observed emission current was plasma limited, that is, insufficient ions were present to remove space charge. An alternative argument shows that if the current was from tantalum in the cathode, the system would have been emission limited if the diode characteristic obtained (Fig. 2) was influenced by geometry.

4. Open-circuit voltages in this case are most likely to be derived from considerations of work function differences, assuming sheath potentials are negligible. Taking differences of published work function values gives values of the right order for open-circuit voltage for a tantalum cathode-tantalum shield circuit. However, these considerations can only be taken qualitatively, since surface conditions changed during the experiment and patch effects undoubtedly play a role also.

5. Resistivity magnitudes indicate a fractional ionization consistent with

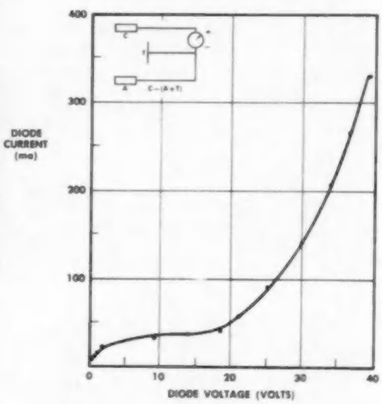

Fig. 2 — Diode characteristics for run with C-(A+T) circuit and following operating conditions: reactor power 800 kw, cathode temperature 1890 K, argon gas, pressure 212 mm of Hg, C-A gap ½ cm, diode resistance between elements C-(A+T) 90 ohms. (C = cathode, A = anode, T = tantalum shield.)

the initial lower theoretical estimate fractional ionization, assuming an emission area and gap consistent with the cathode-tantalum shield circuit.

6. Oxygen outgassing from heated components might be a cause of electron loss by the mechanism of attachment or emitter surface oxidation.

The above shows that, while the experiment demonstrated that space charge neutralization by a fission fragment generated plasma allows a thermionic diode to be operated as an energy converter, it did not conclusively demonstrate whether such a system, under the conditions used in this experiment, will be an efficient means of energy conversion.

To Order Paper No. 120C . . . on which this article is based, see p. 6.

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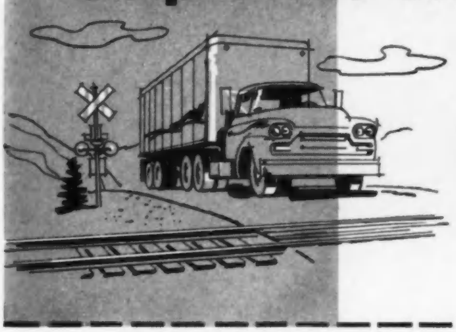

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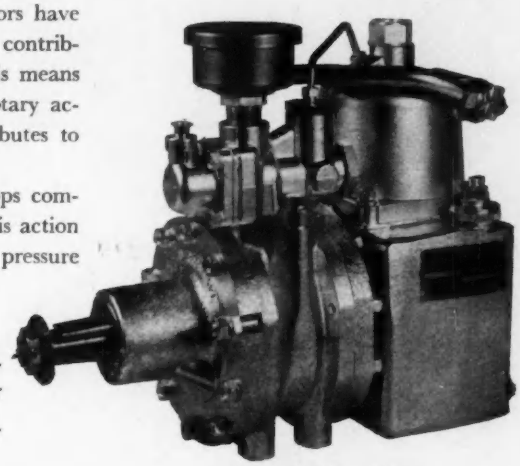

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New Members Qualified

These applicants qualified for admission to the Society between February 10, 1960 and March 10, 1960. Grades of membership are: (M) Member; (A) Associate; (J) Junior.

Alberta Group: Lewis Mark John Townsend (A).

Atlanta Section: W. R. Hill (M).

Baltimore Section: William A. Gray (M), Russell L. Swartz, Jr. (J).

Buffalo Section: Fred B. Ray (M), Raymond E. Seekins (M).

Central Illinois Section: Gerald Junior Bright (A), Earl M. Kerr (A), Daniel O. King (M), Ziedonis Krauja (M), Charles R. Miller (J).

Chicago Section: Robert J. Askevold (M), Harold A. Behnken (M), Clarence J. Bohn (A), Robert Denes (M), Leslie D. Dilworth (A), Donald W. Forsyth (M), Ernest E. Freeman, Jr. (M), Joseph A. Kwiatkowski (J), Norman Ian McClellan (M), George M. Rowley (M), Robert Louis Stverak (A), Joseph Charles Vruno (A), Robert A. White (J).

Cincinnati Section: Dennis P. Townsend (M).

Cleveland Section: Richard L. Gaugler (A), Richard L. Knight (J), Charles Edward Mathay (J), Jack P. Willard (J), Frank Lewis Williams (A), John W. Wolcott, III (M).

Colorado Group: Harold Henry Eurich (J).

Dayton Section: Arthur J. Stilwell (M).

Detroit Section: Eli H. Benstein (M), C. C. Bingaman (M), Herbert Charles Brodsky (J), W. J. Clawson (M), Guy W. Fitch (M), Howard W. Hall (M), Hollway Hubbard (A), Richard H. Jarmon (J), Robert Edwin Joyce (A), John Joseph Konkal, Jr. (J), Clarence D. Lutton, Jr. (J), Boris P. Muchnij (J), James G. Musser, Jr. (J), Wilton D. Nelson (M), George Edward Nies (J), Frederick E. Pokorny (M), John P. Price (A), Raymond Rastenis (J), Francis C. Sering (A), Lawrence P. Sullivan (A).

Fort Wayne Section: Carl William Linder (M).

Hawaii Section: James M. Bailey (J).

Indiana Section: Merwyn R. Jacoby (J), George B. Shaw (M).

Metropolitan Section: Robert W. Dougherty (M), David Kaplan (M), Arthur R. Lytle (M), Edward K. Matthews (J), William B. Miner (J), Harvey R. Nickerson (M), Howard D. Rubenstein (J), Sol. Martin Schusheim (A), Armand A. Small (M), Robert F. Zalokar (M).

Mid-Continent Section: J. Vernon Lawson (M).

Mid-Michigan Section: Carlisle R. Davis, Jr. (J).

Milwaukee Section: George H. Glum (M), Frank J. Kunesh, Jr. (M), David H. Minshall (J), Robert E. Schulz (A), Robert B. Temple, Jr. (J), John H. Winston (M).

Montreal Section: Ronald Alfred Lennard (A), Gerard St. Pierre (A), Dennis Smith (M).

Northern California Section: Daniel J. Gribbon (M).

Northwest Section: Eugene Robert Benner (J), Dean Musche (A).

Ontario Section: William Ralph Brunt, Jr. (J), Bruce M. Campbell (A), Prof. James Stouffer Campbell (M), Frank T. Carter (M), H. G. Ronson (M), John Thompson Sinclair (A), Fred S. Wood (M).

Philadelphia Section: Anthony Francis Benning (M), James A. Heidamos (J), Joseph Thomas Threston (J).

Rockford-Beloit Section: Leonard H. Adams (M), Alfred H. Hagmann (A).

Salt Lake Group: DeVon J. Roper (J).

San Diego Section: Rhada C. Lasley (J).

South California Section: Frank S. Baker (J), Joseph A. Birg (J), Wilson A. Burtis (A), Bernard Maurice De Marr (J), William Joseph Rozinka (J), Frederick B. Safford (M), Mac Fuller Smith (A), Frederick G. Space, Jr. (M).

Southern New England Section: James Nelson Bagnall (M).

Spokane-Intermountain Section: William H. Kinzel (A).

Syracuse Section: Arnold S. Brooker

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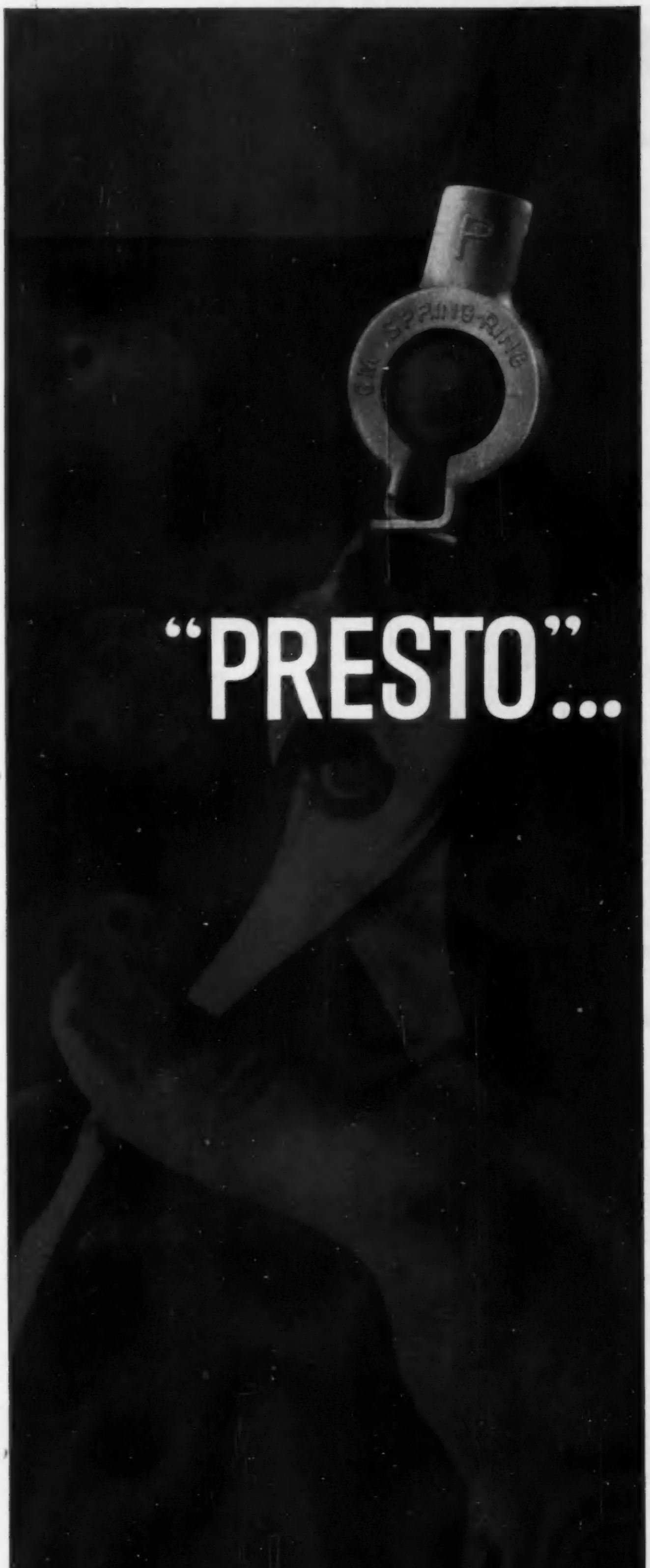

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continued from p. 160

(J), Ricardo H. Vergara (M).

Texas Gulf Coast Section: Kenneth Lee McNemar (M).

Virginia Section: J. T. Howell (M).

Western Michigan Section: Robert Edward Doe (J), Claude E. Robitaille (M).

Outside Section Territory: Joseph E. Link (J).

Foreign: Carlton G. Agle (M), West Germany; Gerhard Benteler (M), Germany; Kenneth Forbes Brown (A), Malaya; Robert Buty (M), France; Charles Evelyn Jones (M), Australia; Jan Kraay (M), Belgian Congo; T. K. Viswanathan (J), India.

Applications Received

The applications for membership received between February 10, 1960 and March 10, 1960 are listed below.

Alberta Group: Vincent John Kaytor

Atlanta Section: J. R. Carmell

British Columbia Section: Francis R. Madore

Buffalo Section: James Thomas Albert, George Barboza, Roland N. Crossley, W. Russell Laidlaw, Robert D. Russell

Central Illinois Section: Ronald S. Anderson, Gale C. Barton, B. A. Berkeland, Harry M. Bloom, Jerald Dwight Gentry, Ronald J. Hartmann, Robert T. Krumtinger, Bobby Joe Orr

Chicago Section: Roy S. Brandon, Douglas William Dickinson, Robert L. Fels, Richard E. Gerhardt, James Andrew Gray, Sr., Robert Paul Heffernan, Walter E. Larkin, Clifford R. Linker, Jerry A. Lupton, William F. Martin, John Joseph Nelson, Phillip Pines, Thomas H. Reddington, Warren C. Schloskey, Donald H. Shook, Donald Michael Szymanski, Peter Teenstra

Cincinnati Section: Russell E. Single

Cleveland Section: Joseph V. Bosilievic, Russell DeYoung, Richard G. Gebhardt, Victor Holt, Jr., James D. McCaskey, Chester R. Mielke, J. Carl Peifer, Joseph Thomas Podnar, Paul W. Sandrock, Francis Sevik, Stanley J. Sobolak, H. Lansing Vail, Jr., George R. Voss

Dayton Section: Alexander A. LePera

Detroit Section: Albert Willard Armour, J. Louis Barribeau, Donald F. Buser, Charles G. Chase, Traian T. Comsa, Norman Eugene Coonfer, William F. Darin, Raymond F. Darney, Harry P. DeMoss, John W. Duffy, James L. Eyre, L. D. Gschwind, George W. Hain, Thomas A. Harris, John W. Hogan, R. B. Holmes, Shyr-ing Hu, Donald A. Hulett, A. P. Stanley Hyde, Martin S. Kilsdonk, Gerald L. Knight, Joseph E. Lober, Eugene C. McNeil, John H. Mieras, Arthur William Moesta, Jr., George C. Motorojescu, John E. Morton, Victor A. Nawrocki, William J. Papp, David W. Patch, Rob-

continued on p. 165

York, Stanley Young

Western Michigan Section: Robert E.

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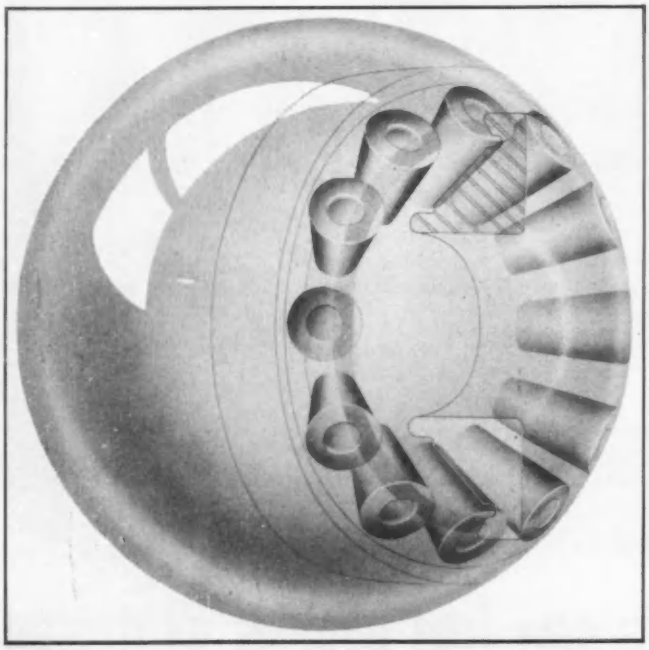
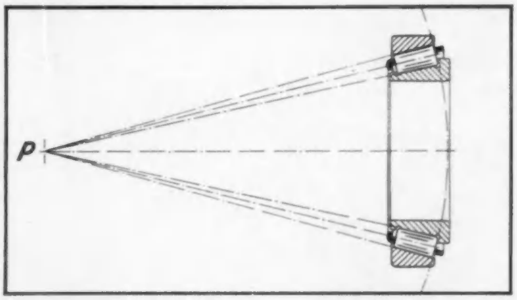


When you require bearings, we suggest you consider the advantages of Bower bearings. Where product design calls for tapered or cylindrical roller bearings or journal roller assemblies, Bower can provide them in a full range of types and sizes. Bower engineers are always available, should you desire assistance or advice on bearing applications.



True rolling of tapered bearing elements depends upon maintaining a true spherical radius during manufacture.

For a tapered roller bearing to achieve maximum performance, i.e., maximum life and capacity under load, it must have true sphericity — a condition of bearing geometry which permits true rolling of the tapered rollers in the raceway.

True rolling in tapered bearing elements is the result of maintaining a critical geometric relationship between the raceways and the contact surfaces of each roller. True rolling is essential to maximum performance. Without it, premature bearing failure is certain.

As engineers know, a tapered roller will describe a true circle when rolled on a plane surface. *It will always roll in this one path precisely, without sliding or skewing.* But to put true rolling to work in a bearing which can carry both heavy thrust and radial loads, it is essential that the rollers *and* the raceway have a true spherical radius, or sphericity. The drawing illustrates this condition.

If each roller in the bearing were to be extended in length, while retaining its taper, it would form a cone, terminating at point "P". All cones generated from all rollers would meet at point "P", which is also the center of the hypothetical sphere shown. The surface of the sphere would *touch all points on each roller's head!*

In effect, then, each roller's taper determines the radius of a hypothetical sphere whose surface, in turn, determines the correct contour for each roller head. Only when these conditions are satisfied in design, and when they are rigidly held during manufacture, will true rolling take place. In the manufacture of each Bower tapered roller bearing, sphericity is held within extremely narrow limits by means of special Bower-designed precision grinders. The consistent accuracy possible with these machines is one major reason why Bower roller bearings provide maximum performance under all speeds and loads up to the bearing's maximum rating.

BOWER ROLLER BEARINGS

BOWER ROLLER BEARING DIVISION — FEDERAL-MOGUL-BOWER BEARINGS, INC., DETROIT 14, MICHIGAN

Applications Received

continued from p. 162

ert D. Petrie, Gerald R. Reynolds, Nolan A. Ryan, Donald J. Schrage, Jewell Richard Smith, Ronald F. Steinmayer, John Brixton Swetka, Martin Tomka, Andrew J. Van Hoef, Lino F. Widmann, George H. Wolenter, James C. Wood, John S. Wreford

Fort Wayne Section: Subhas Chandra Ghorai

Indiana Section: Warren C. Letsinger, Thomas A. Stewart, John William Van-Way

Kansas City Section: George C. Hilaire, Jr.

Metropolitan Section: Charles A. Ashby, III, Charles Atlas, Jr., William Morrison Dempsie, Cord Lipe, Roger A. Michaels, Robert Pollock, Stuart M. Sachs, Donald J. Smith, Wayne J. Wheeler

Mid-Michigan Section: Robert P. Hendrichs, Louis H. Ravitch

Milwaukee Section: James A. Meyer, Paul Rumachik, Richard Thomas Scantlebury, David Schmitz, Arthur James Slingerland

Montreal Section: John S. Bell, Jean Brunelle

New England Section: Edward P. Trider, George Nicholas Tsimekles

Northern California Section: Jesse A. Honeywell, Edward M. Ritts

Ontario Section: Richard F. G. Baker, Duncan Alexander Brodie, Donald M. Campbell, Ralph G. Codner, Leslie Crichton, Werner Ron Eschrich, Lorne F. Hiller, Donald A. Jackson, William Robert Moggridge, George Raymond Porter, C. M. Roberts, Robert Elgin Parkinson, Ron W. Todgham

Oregon Section: Alfred Calderaro

Philadelphia Section: Donald J. Klopp, Louis Levin, Alexander Tarsi

Rockford-Beloit Section: Burdette L. Douglass, Norman L. Rice

St. Louis Section: Lawrence E. Nienaber

Salt Lake Group: Stephen James O'Brien

Southern California Section: Michael Dzama, Kent H. Fisher, Victor Francis Hickey, D. Frank Howeth, Morris Kramer, Jerry C. Morrison, Paul G. Pace, William James Scott, Everett H. York, Stanley Young

Southern New England Section: Girard S. Haviland, George Richard Krohne

Syracuse Section: George T. Jarrett

Texas Section: M. A. Atkins, Woodrow P. Silverman

Twin City Section: Russell W. Daniels, Richard N. Ohman

Washington Section: David A. Didion

Western Michigan Section: Robert E. Bishop, Richard B. Borman, Melvin F. Brugger, Jerome D. Welczak

Wichita Section: Evans Glenn Freese

Outside of Section Territory: William Ronald Brookes, Donald Murray, Richard P. Schaeffer, George Sklar, John Lawrence Twells

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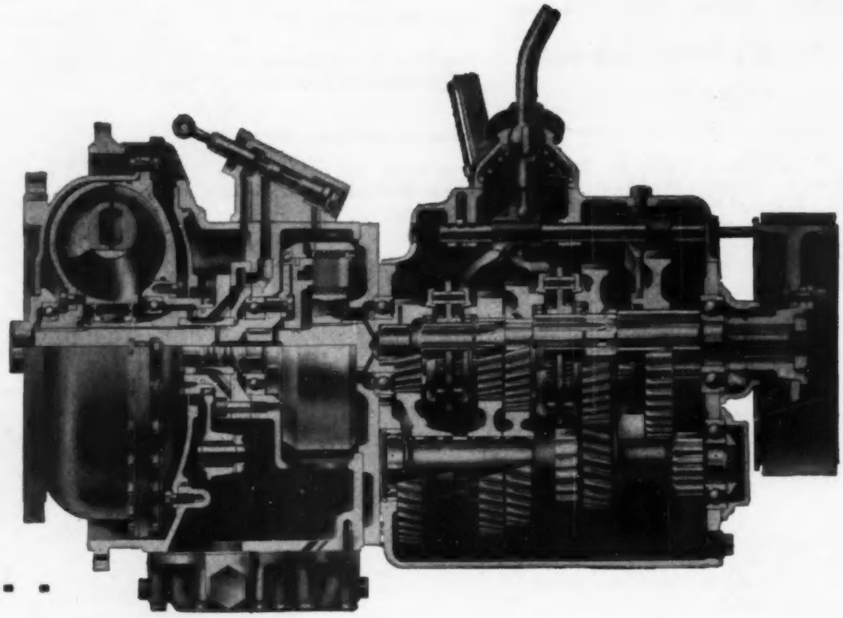

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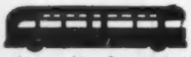

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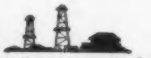

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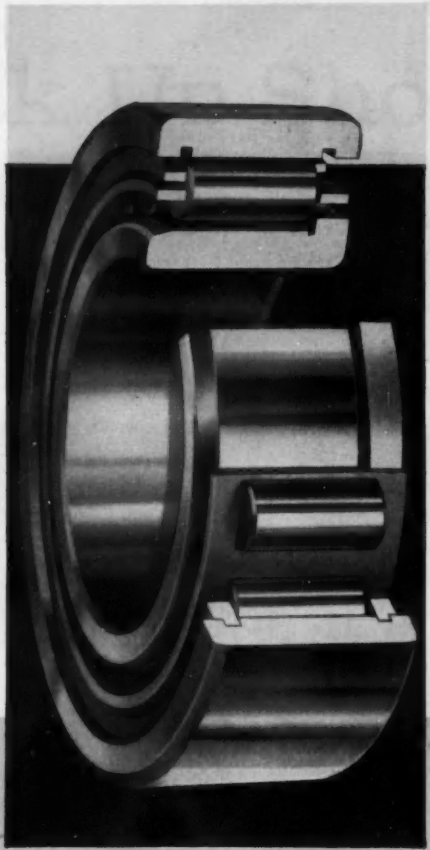


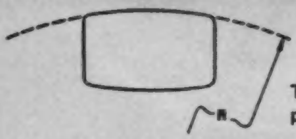
Aetna
ROLLER BEARINGS

True Crowned for 15% longer service life

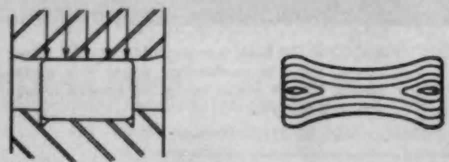
Because each Aetna roller is *True Crowned* with a large radius, high stress points in the rollers are relieved—giving 15% longer bearing life. The crown radius is scientifically determined and varies with the roller size.

Aetna offers a wide range of self-contained *True Crowned* pure radial roller bearings in both custom and standard designs—also many special designs of both pure radial and pure thrust bearings for unusual applications.

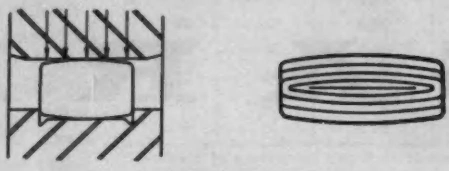
For complete information on *True Crowned* Aetna Roller Bearings, call your Aetna representative listed in your classified telephone directory, or write for General Catalog and Engineering Manual.



True Crowning as produced by Aetna.



Straight roller showing stress pattern at roller to race contact.



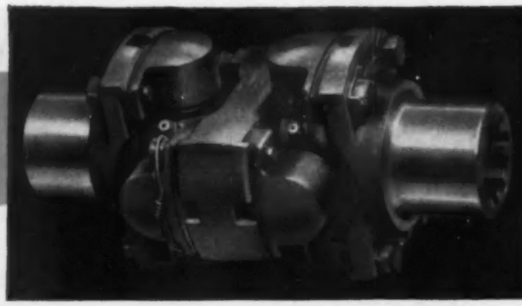
True Crowned roller showing stress pattern at roller to race contact.

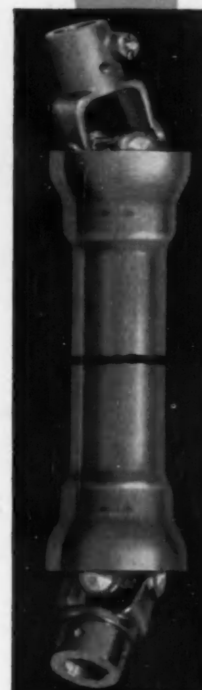
AETNA BALL AND ROLLER BEARING COMPANY
DIVISION OF PARKERSBURG-AETNA CORPORATION

4600 SCHUBERT AVE.
CHICAGO 39, ILL.

ANTI-FRICTION SUPPLIERS TO LEADING ORIGINAL EQUIPMENT MANUFACTURERS SINCE 1916


W-6
REPAIR TIME
JUST 4 HOURS



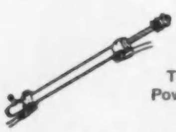



GO

Load-Levelers* by Monroe Prevent "Tail  Drag"

MONRO-MATIC SHOCK ABSORBERS

Standard on more makes of cars than any other brand.



DIRECT ACTION POWER STEERING

The only truly direct-action Power Steering units available.

MONROE SWAY BARS

Specified as standard equipment on 15 makes of passenger cars.

E-Z RIDE TRACTOR SEATS

Standard on more tractors than all other seats of its kind combined.

Prevent bumping on driveways and all the other problems caused by overloading today's longer, lower cars. Load-Levelers* give 35% to 45% more road clearance with overload, 12% to 17% more road clearance with normal load.

Load-Levelers* do the work of elaborate suspension systems—at a fraction of the price. Installed in place of the rear shock absorbers, they automatically adjust a car to any extra load, to provide a safe, comfortable ride.

- Prevent "tail drag", side sway, and "bottoming" on axles . . . provide a smoother stable ride.
- Prevent hard steering and excessive tire wear.
- Require no service, and don't interfere with underbody servicing.
- Easily installed as optional equipment.

Our engineers will be glad to discuss the many advantages of Load-Levelers*. Write or call today.

MONROE

Load-Leveler
TRADE MARK
STABILIZING UNIT

*Trademark

MONROE AUTO EQUIPMENT COMPANY • MONROE, MICHIGAN

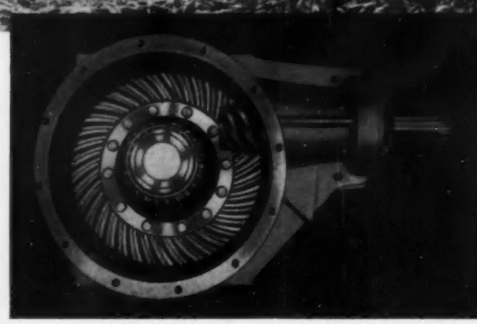
In Canada, MONROE-ACME LTD., Toronto, Ontario • In Mexico, MEX-PAR, Box 21865, Mexico City

WORLD'S LARGEST MAKER OF RIDE CONTROL PRODUCTS, INCLUDING MONRO-MATIC* SHOCK ABSORBERS

From WARNER AUTOMOTIVE...

a STRONGER, yet LIGHTER

HAY BALER GEAR BOX BUILT BY B-W



Developed by Warner Automotive to Help CASE Engineers Solve a Problem...

The problem: To design a simplified, foolproof, surge-free power train for the CASE Model 200 SweepFeed Hay Baler at a cost that would justify its purchase by farm operators.

World-famous CASE engineers searched for months for a suitable gear box . . . rugged, dependable, yet lightweight. They brought their problem to Warner Automotive engineers, specialists in mechanical power transmission. Warner produced a large, high capacity gear box that successfully withstood the most exhaustive tests CASE engineers could devise for it. All CASE 200 Hay Balers are now equipped with this B-W Gear Box.

CONSULT OUR ENGINEERS FOR TRANSMISSION GEARS, GEAR ASSEMBLIES, RING GEARS AND PINIONS, DIFFERENTIAL PARTS AND ASSEMBLIES, POWER TAKE-OFFS, SPLINED SHAFTS

- Housing of a *malleable* iron—lightweight, but stronger and more rigid.
- Hypoid gears, carburized for long life.
- Integral ring gear carrier and splined crankshaft.
- Tapered root spline on input shaft.
- Anti-friction bearings throughout.

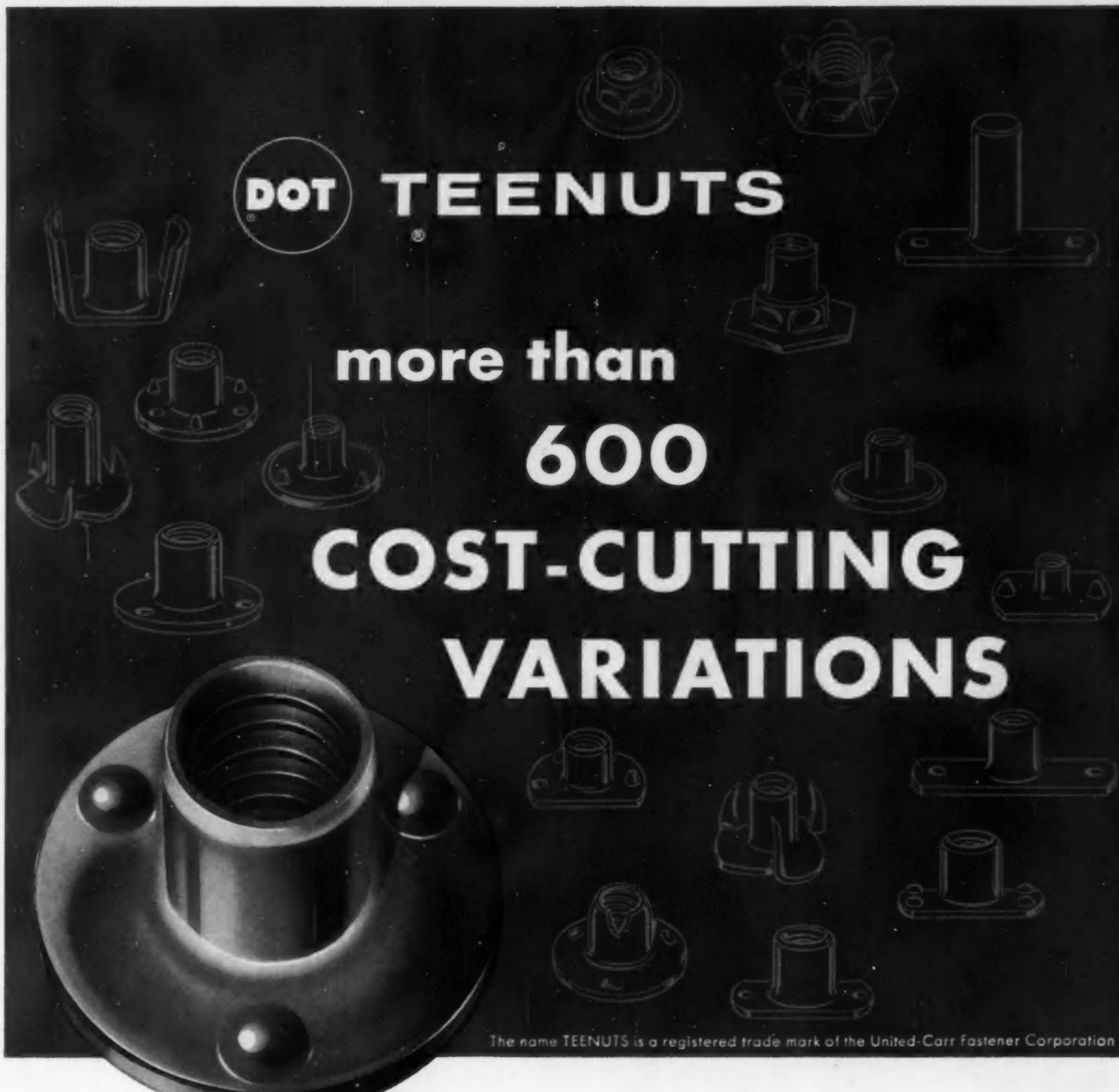
B-W

WARNER AUTOMOTIVE DIVISION

BORG-WARNER CORPORATION

Auburn, Indiana

IT'S A BETTER PRODUCT WHEN BORG-WARNER HAS A PART IN IT



Since the first TEENUT was developed by Carr Fastener in 1927, more than 600 different modifications of this extremely versatile device have been designed and manufactured in true, mass-production quantities.

By combining nut and washer in one solid unit, the DOT TEENUT offers exceptional strength and security and eliminates the need for tapping. Its flanged base can be formed with welding bosses for attachment to sheet or solid metal structures . . . with prongs for wood . . . or with any number of different special bases for particular applications. DOT TEENUTS can be made in heat and corrosion-resistant materials and they can be provided with moisture-seals and vibration-proof, self-locking barrels.

Once mounted, the DOT TEENUT stays put and can't be lost or mislaid . . . an advantage at any time and a necessity where blind fastening is required.

Wide experience in the proper application of DOT TEENUTS and a multitude of other special-purpose fasteners enables your DOT field representative to provide prompt and effective solutions to a tremendous variety of fastening problems. Where special design work is needed, he can bring you the services of a design-engineering group unequalled in its field.

The DOT TEENUT catalog is an invaluable reference . . . yours on request.

MAKERS OF ★ DOT ★ FASTENERS

CARR FASTENER COMPANY

Division of UNITED-CARR Fastener Corp., Cambridge 42, Mass.

Offices In:

Atlanta, Boston, Chicago, Cleveland, Dallas, Detroit, Los Angeles, New York, Philadelphia, Syracuse

In New Trucks or Old—

EATON INDUCTALLOY AXLE SHAFTS

LAST 3 to 10 TIMES LONGER

Through billions of miles of heavy-duty service, Eaton Inductalloy Axle Shafts have proved their ability to deliver superior performance. Freedom from break-down—more time on the road, less time in the shop—plus thousands of trouble-free miles added to axle life, mean lower over-all operating cost.

Eaton's exclusive method of dual hardening truck axle shafts produces an extremely hard case extending deep into the material structure, and enables Inductalloy Axle Shafts to handle more work and abuse without fatigue failure.

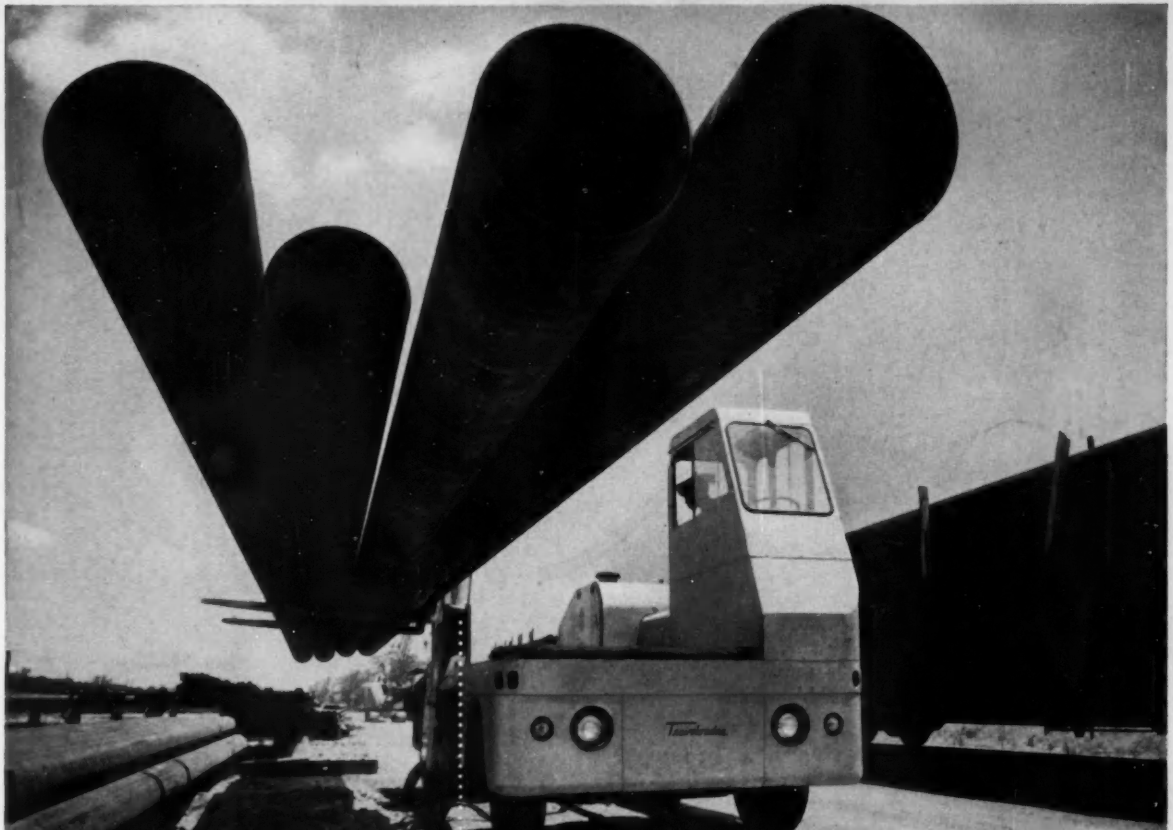
Eaton Inductalloy Axle Shafts are available not only in new axle equipment, but also as replacements for earlier models.

EATON INDUCTALLOY SHAFT

ORDINARY AXLE SHAFT

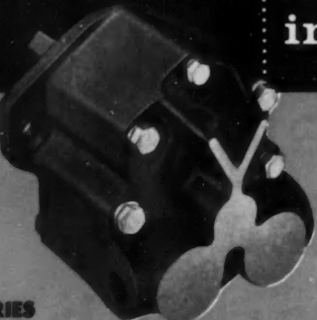
EATON — AXLE DIVISION — MANUFACTURING COMPANY

CLEVELAND, OHIO



DYNAMIC DIFFERENCE

in hydraulic performance



"HC" SERIES

POSITIVE DISPLACEMENT GEAR-TYPE PUMP

Shaft seal: lip type
Drive: direct, gear or belt
Capacity: 5 sizes, 5 - 17 gpm
Pressures: to 1500 psi
Operating speeds: to 2400 rpm
Porting: side (Std.) end (Opt.)
Valve: Optional; internal relief, adjustable 800 - 1500 psi

BULLETIN HY11 gives complete engineering characteristics — performance and installation data.

Call the man from Webster

. . . he's one of a staff of engineers, specially trained in hydraulic application. He can help you solve special problems when hydraulics become a part of your design!

photo: Baker Industrial Trucks, div. of Otis Elevator Co., Cleveland, O.

Webster

POSITIVE DISPLACEMENT GEAR-TYPE PUMPS

Yesterday's pipe dream is today's nimble-fingered reality. This versatile fork lift truck unloads and stacks — carries a full platform load. The heart of its powerful hydraulic system is a Webster Gear-Type Pump. Just another example of Webster's practical and economical adaptation to hundreds of hydraulic applications . . . in lift systems, pressure lubricating, oil circulating . . . in industrial, agricultural and construction equipment.

Webster Gear-Type Pumps present many advantages in design "fit" and application — with unusual standardization and interchangeability of components. Keep Webster in mind when you plan hydraulics — for the dynamic difference that pays!

OIL HYDRAULICS DIVISION

WEBSTER ELECTRIC
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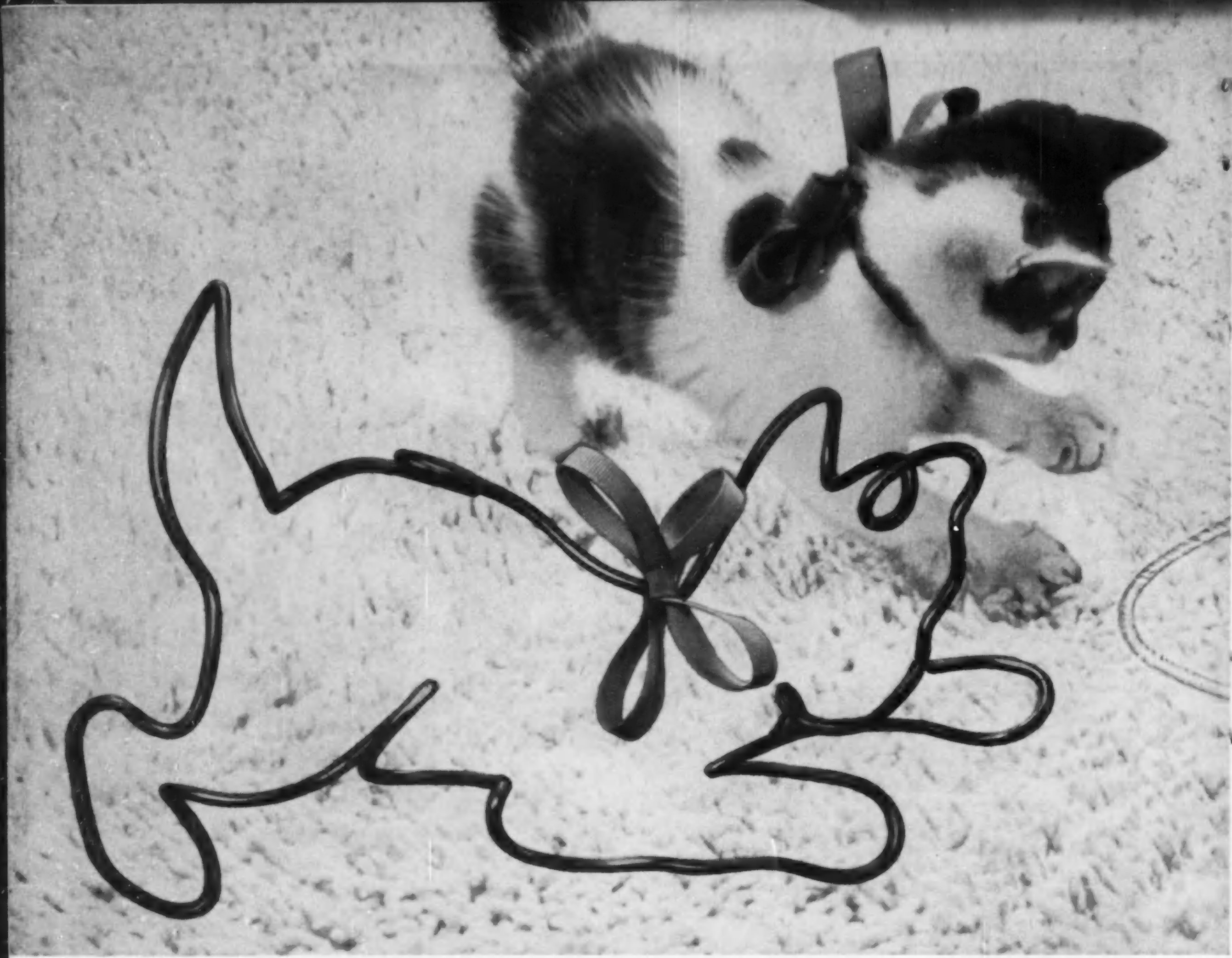


There's almost no limit to the things Bundy can mass-fabricate

Bundyweld is the original tubing double-walled from a single copper-plated *steel* strip, metallurgically bonded through 360° of wall contact for amazing strength, versatility.

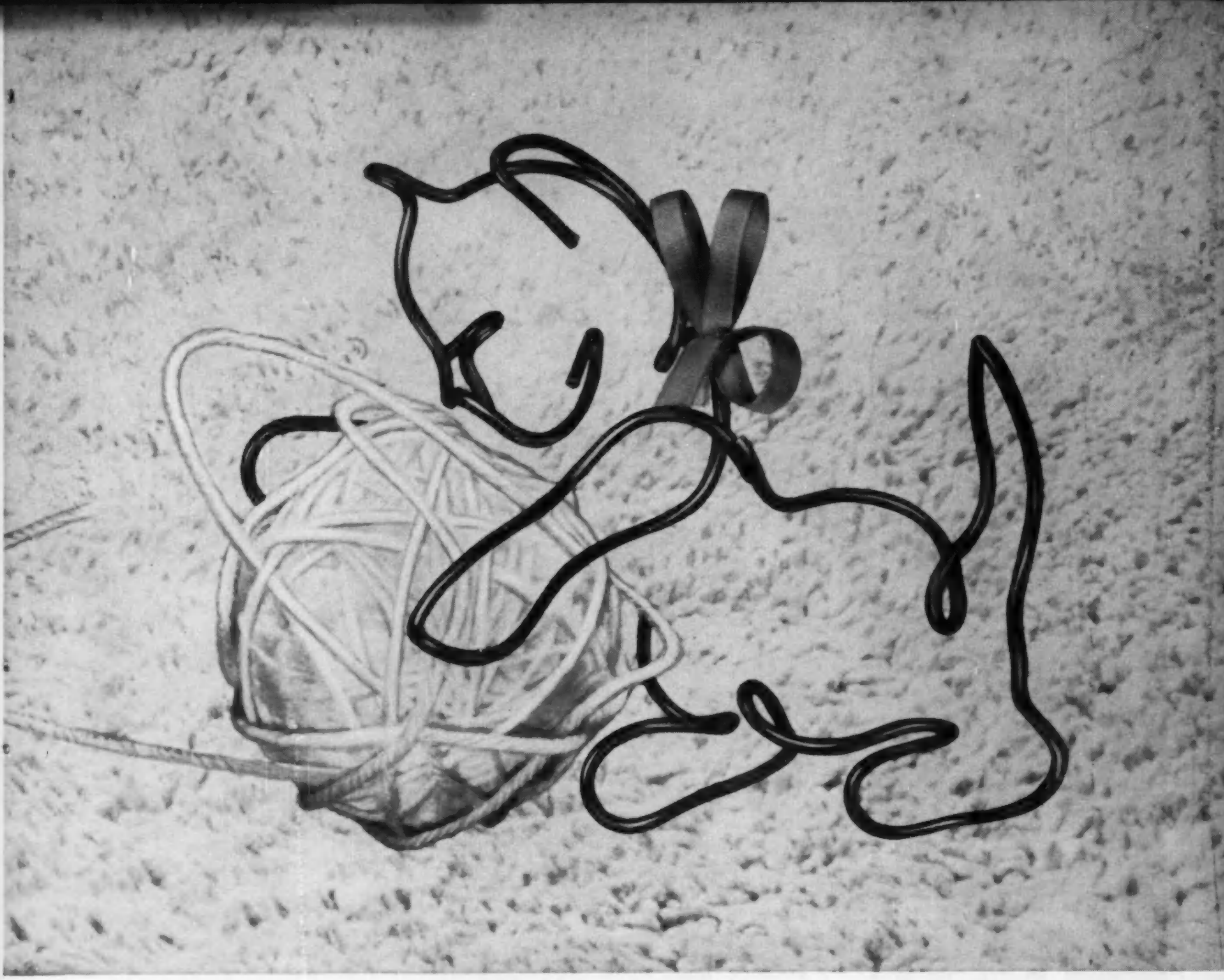
Bundyweld is lightweight, uniformly smooth, easily fabricated. It's remarkably resistant to vibration fatigue; has unusually high bursting strength. Sizes up to ⅝" O.D.

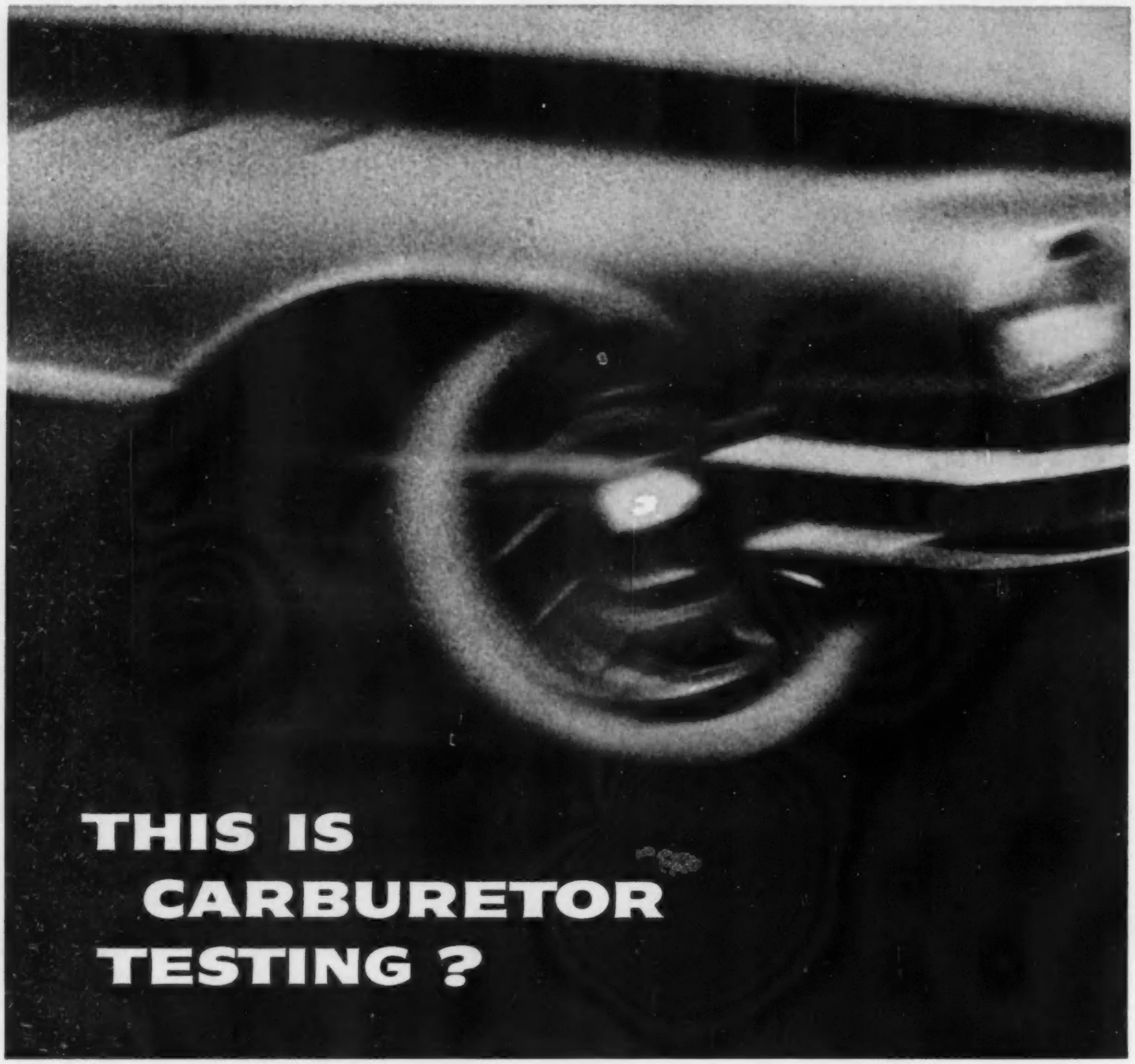
Experience makes the difference! And Bundy engineers, backed by years of experience in designing and fabricating tubing parts, can help you solve your tubing problem.

Bundy engineers will work with you at any time during the development of your product. They may be able to suggest design modifications in your tubing components to cut fabrication costs. Then your design will be turned over to Bundy specialists who will mass-fabricate your tubing parts at low unit cost with Bundyweld®.

Bundyweld is the original steel tubing that's ***double-walled*** from a single steel strip for extra strength and resistance to vibration fatigue. It's the safety standard of the automotive industry. Bundyweld is covered by Government Spec. MIL-T-3520, Type III.

Got a tubing problem? Bring it to Bundy. Call, write, or wire: Bundy Tubing Company, Detroit 14, Michigan.





it certainly is, for maneuvers such as this abrupt cornering set up unusual liquid displacement and mechanical stress conditions. Rochester-GM Carburetors are built to function without a whisper of complaint throughout such tests. This one was at the GM Proving Ground at Milford. Others go on at the GM Desert Proving Ground in Arizona and, of course, we never cease testing right here in the factory. Rochester-GM Carburetors are expected to please the ultimate consumer, the dealer, his service people and those hardest of all to please—the car engineers. We leave no stone unturned to see that you—wherever you are in this chain—are satisfied with Rochester-GM Carburetors. *Rochester Products Division of General Motors, Rochester, New York.*

GM

America's number one original equipment carburetors

ROCHESTER CARBURETORS

GENERAL MOTORS

One of a series

Payoff in portable photons

Samarium-145, Samarium-153, Gadolinium-153.
Scientists at the General Motors Research Laboratories began three years ago to measure and re-evaluate the nuclear characteristics of these rare earth isotopes — their half-lives, photon emissions, thermal neutron cross sections.

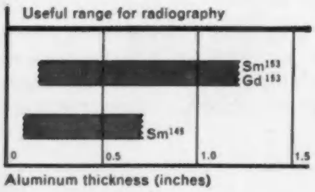
Conclusion: the radioisotopes had attractive possibilities in industrial and medical radiography, emitting almost pure gamma rays or X-rays (photons) in the low energy range of 30 to 100 kev.

The transition from research to hardware came through two key developments. First, cermet pellets were fabricated using only a few milligrams of the rare earth oxides. Then the irradiated pellets were packaged in special bullet-size holders.

The resulting small, sealed radiographic sources are now being field and laboratory tested. Two excellent applications: "inside-out" checks of hollow shapes inaccessible to X-ray tubes, and radiography of thin steel sections and low density materials such as aluminum or human bone. For example, a recent medical milestone was a chest radiograph of a living person made with a Sm^{153} source. The portable exposure unit to shield the source weighed only 18 pounds.

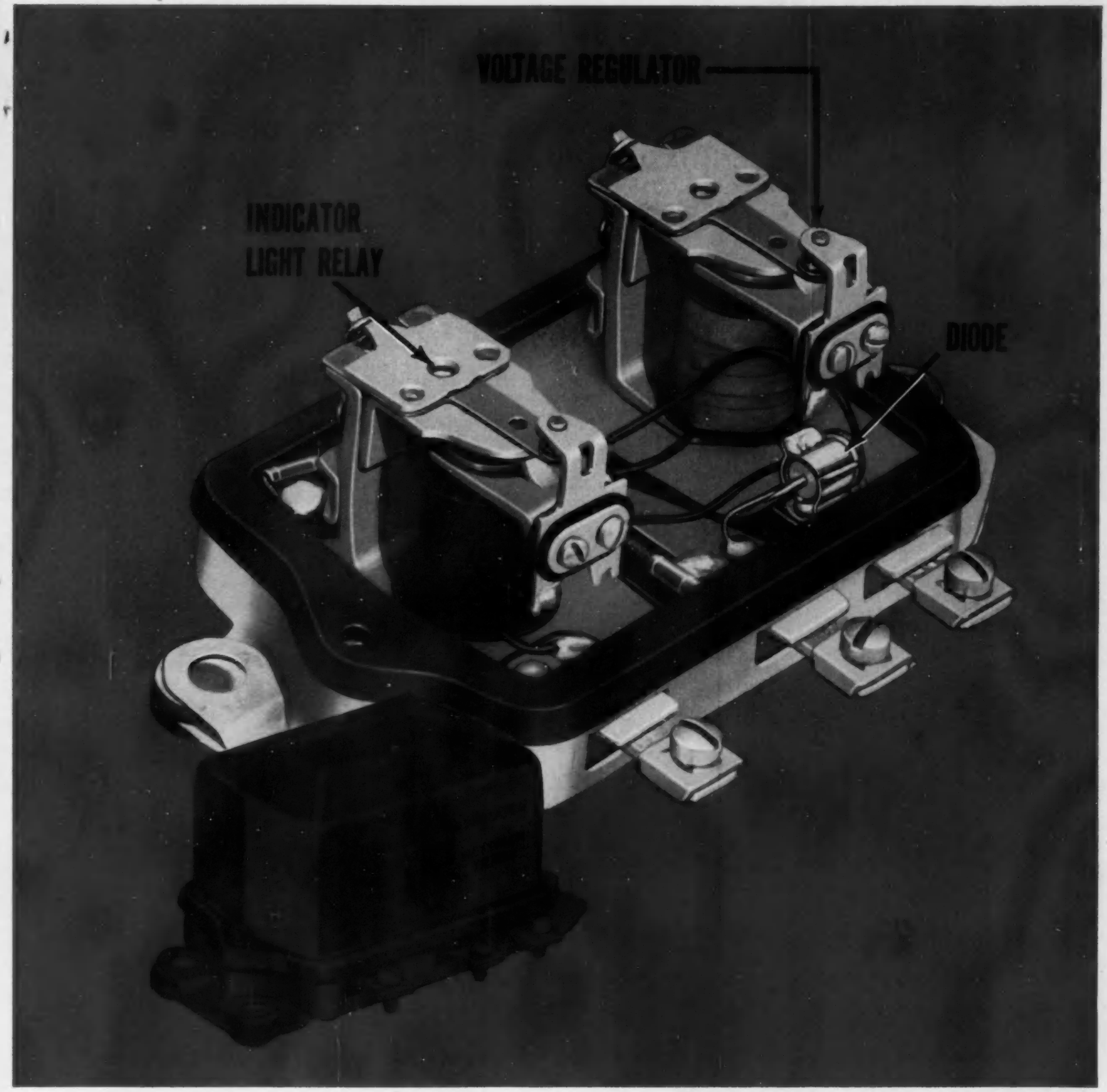
This isotope radiography program is but one example of the work underway in GM Research's modern isotope laboratory — work that means, through science, "more and better things for more people."

General Motors Research Laboratories
Warren, Michigan



Aluminum thickness (inches)


Sm^{153} exposure unit.



AND TRANSISTORIZED VOLTAGE REGULATORS

permits high field current for improved generator performance with low non-inductive current through the contacts for greatly extended contact life. Models are available for circuits containing either ammeters or indicator lights. All units are temperature compensated to better match battery voltage requirements.

Both the full-transistor and the transistorized models have the same mounting dimensions as standard regulators.

Whichever model you choose for your new vehicles or for replacement on present ones, you can be sure of reduced servicing and extended battery life. Available from your car or truck dealer or through the United Motors System.

FROM THE HIGHWAY TO THE STARS

Delco-Remy

ELECTRICAL SYSTEMS

GM GENERAL MOTORS

DELCO-REMY • DIVISION OF GENERAL MOTORS • ANDERSON, INDIANA

BARBER-GREENE specifies INTERNATIONAL Power

for world's leading line of asphalt plants!

Report from Guy Banister,
Chief Technical Engineer,
Barber-Greene Co., Aurora, Ill.

"We standardized on International diesels for Barber-Greene Continuous Mix Asphalt Plants in 1947, and owners' reports prove we made an excellent choice."

"For 30 years Barber-Greene Continuous Plants have played a major role in making asphalt paving the world's most used road surface. Since the 30's road builders have been able to produce a controlled high-quality mix in high volume at low cost, and that calls for *efficient power.*

"Because the whole paving operation depends on our plants for asphalt production, plant downtime can run as high as $5,000 hourly. And since engines on the plants operate under continuous load 8 to 10 hours daily—that calls for *dependable power.*

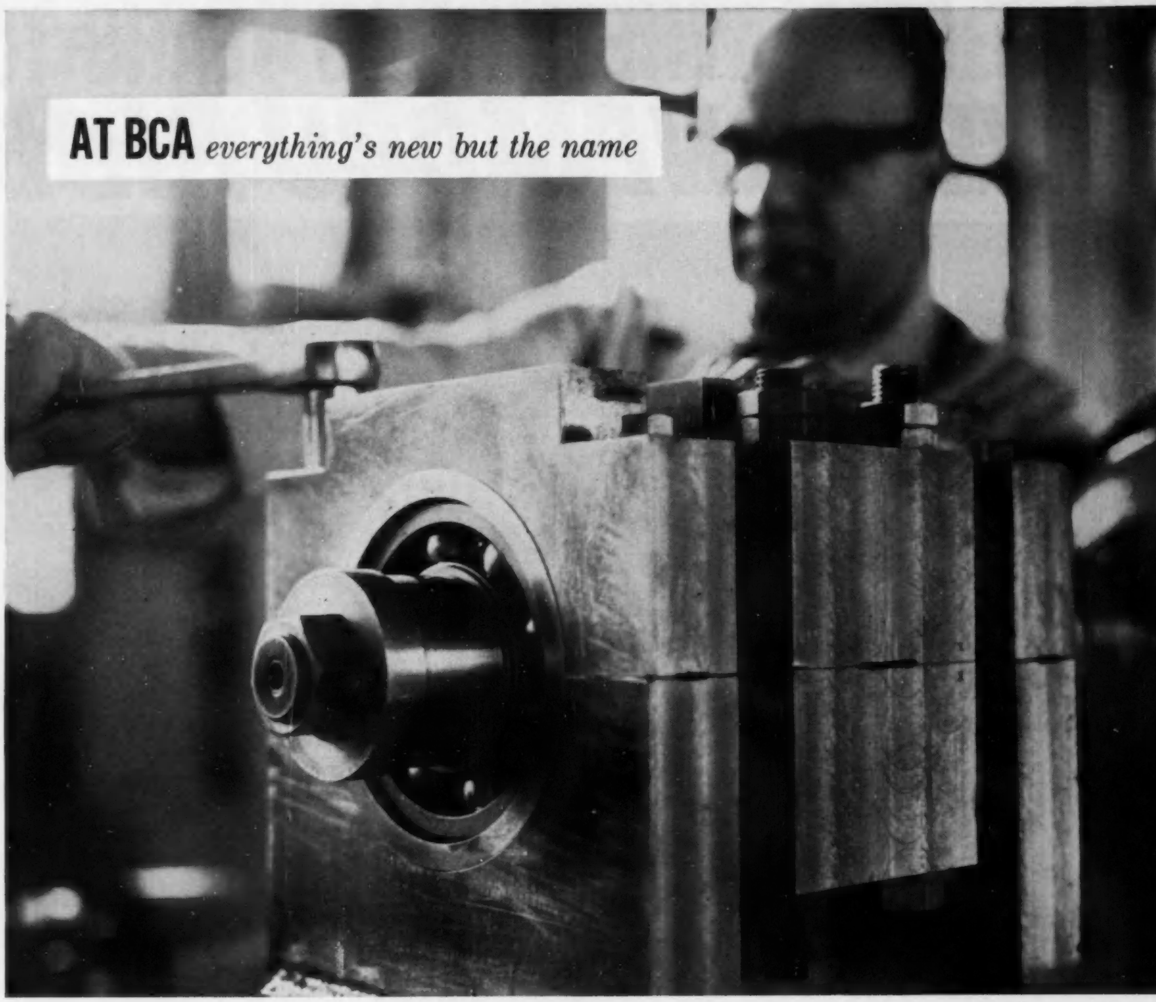
"Since Barber-Greene Continuous Mix Plants are highly mobile—often moving to 6 or 8 jobs in a season—that calls for engines supported by an *excellent parts and service organization.*

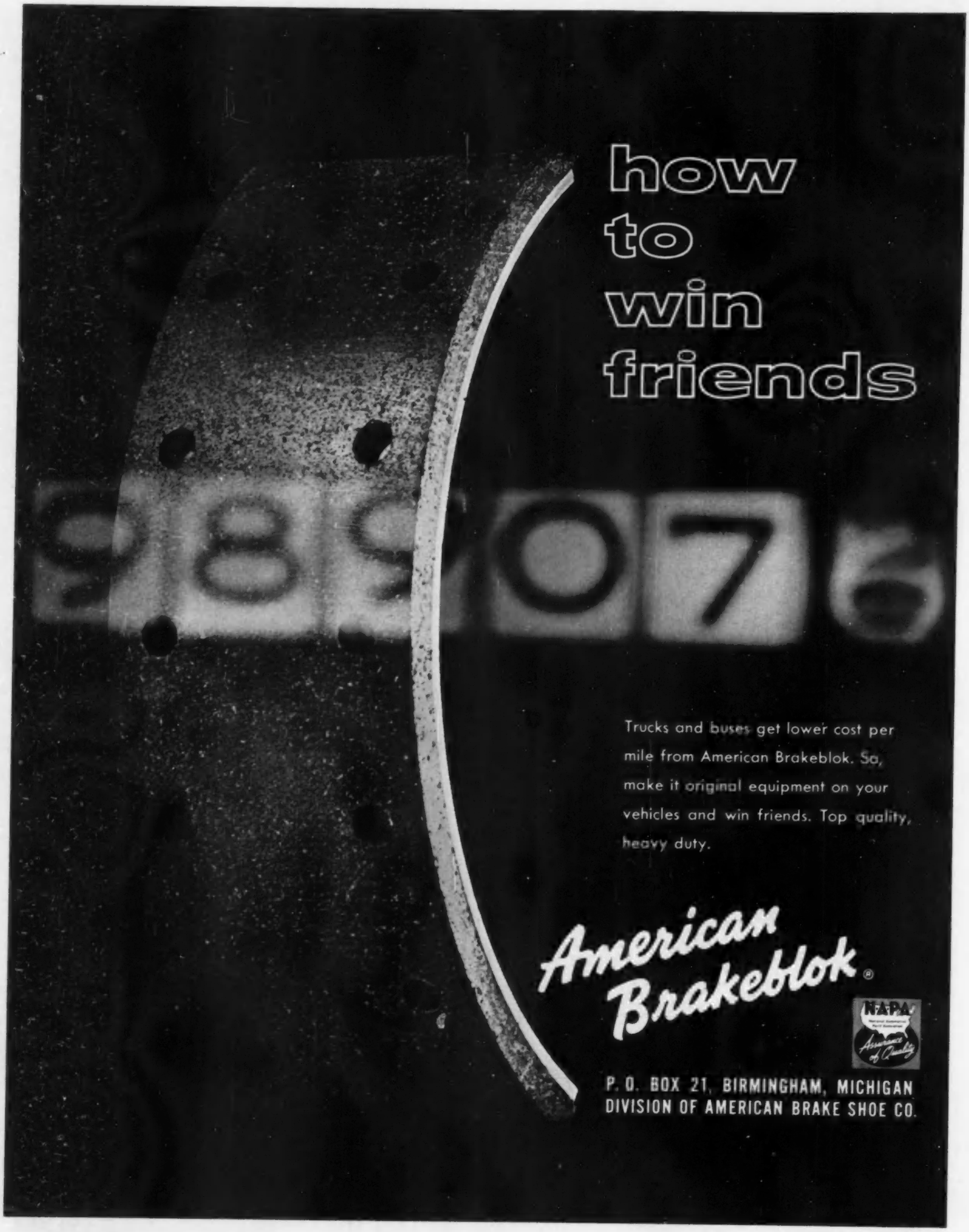
"International diesel engines meet Barber-Greene standards for efficiency, dependability, and parts and service support. That's why we standardized on IH power for these plants. Performance records over the past 13 years show that our customers, too, are satisfied International users."

You, too, can build into your products the advantages of International power. Check the complete International engine line—32 carbureted and diesel models from 16.8 to 385 max. hp. You'll like the one common feature of all 32 engines: fastest payback power for users. Just call or write International Harvester Co., Engine Sales Department, Construction Equipment Division, Melrose Park, Ill.

INTERNATIONAL® IH ENGINES

International Harvester Co.,
180 North Michigan Ave.,
Chicago 1, Illinois
A COMPLETE POWER PACKAGE


AT BCA everything's new but the name



AMERICAN BRAKEBLOK

BREATHER-FILTER

protects housings, crankcases, storage tanks.

The Air-Maze breather-filter keeps dust out of engine and compressor crankcases, gearcases, hydraulic equipment, liquid storage tanks and machinery. Types and sizes available in both oil-wetted and oil bath models to protect every vented housing.

In the oil-wetted type, dust is impinged on a series of oil-wetted wire baffles. In the oil bath type, used where the dust concentration is unusually high, the filter media is enclosed in a bowl. Outside air must first pass through the oil, then the filter media, before entering crankcase or housing. Also functions as a backfire flame arrester.

Available in sizes from 1/8" to 3 1/2". Permanent, all-metal, easily cleanable. Write for booklet BC-453. Air-Maze Corporation, Department SJ-4, Cleveland 28, Ohio. (Subsidiary of ROCKWELL-STANDARD Corporation)

16 NEW and 10 REVISED

Aeronautical Standards, Recommended Practices and Information Reports

were Issued

March 1, 1960

30 NEW and 41 REVISED

Aeronautical Material Specifications

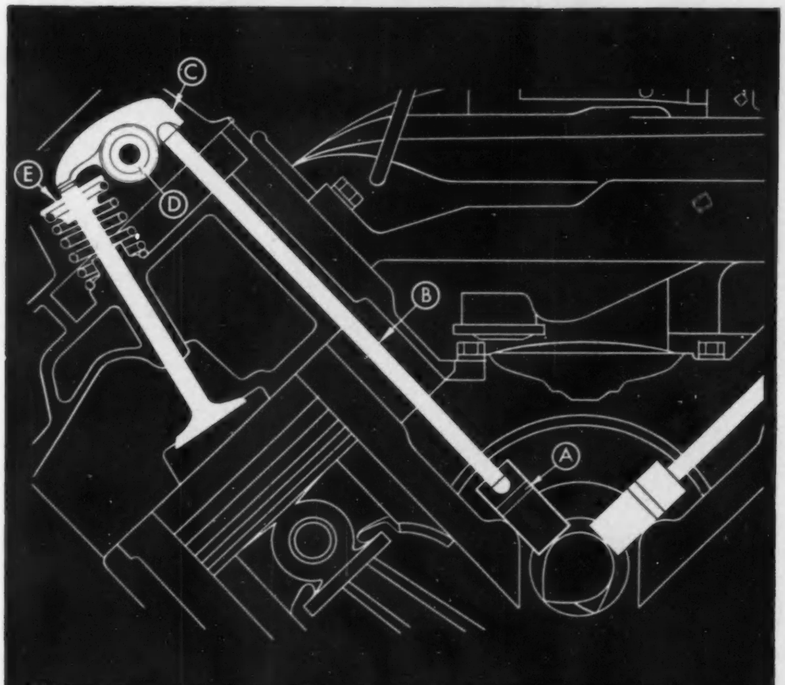
were Issued

Jan. 15, 1960

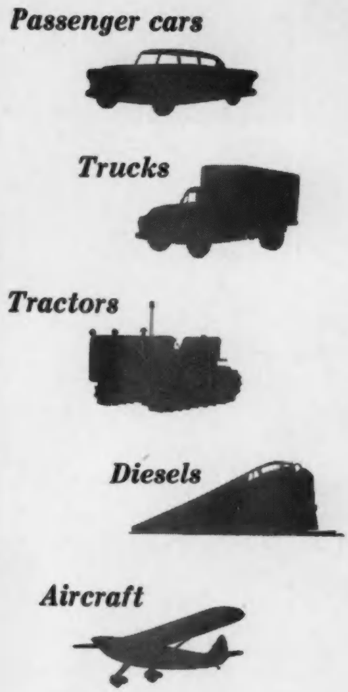
For further information please write

SOCIETY OF AUTOMOTIVE ENGINEERS, INC.
485 LEXINGTON AVE., NEW YORK 17, N. Y.

For all engines - - -



Chicago valve train parts in a typical V-8 automotive engine: (A) Hydraulic tappet, (B) push rod, (C) rocker arm, (D) rocker shaft, (E) valve spring retainer.



Everything you need in valve gear

from CHICAGO

Here at Chicago you'll find a single source for everything you need in valve gear. These specialized facilities are solving problems and saving money for leading engine manufacturers . . . and can do the same for you.

Design and Engineering—at Chicago you'll find valve gear engineering experience in depth . . . men who understand your problems and will work with your engineering staff in designing cam shafts and complete valve gear assemblies for any type of engine.

Manufacturing—Chicago is a leading manufacturer of valve train parts. Our complete line includes precision-made hydraulic and mechanical tappets; push rods in both lightweight tubular and solid styles; valve adjusting screws including new self-locking screws that cut assembly costs; valve spring retainers; rocker arms and rocker shafts.

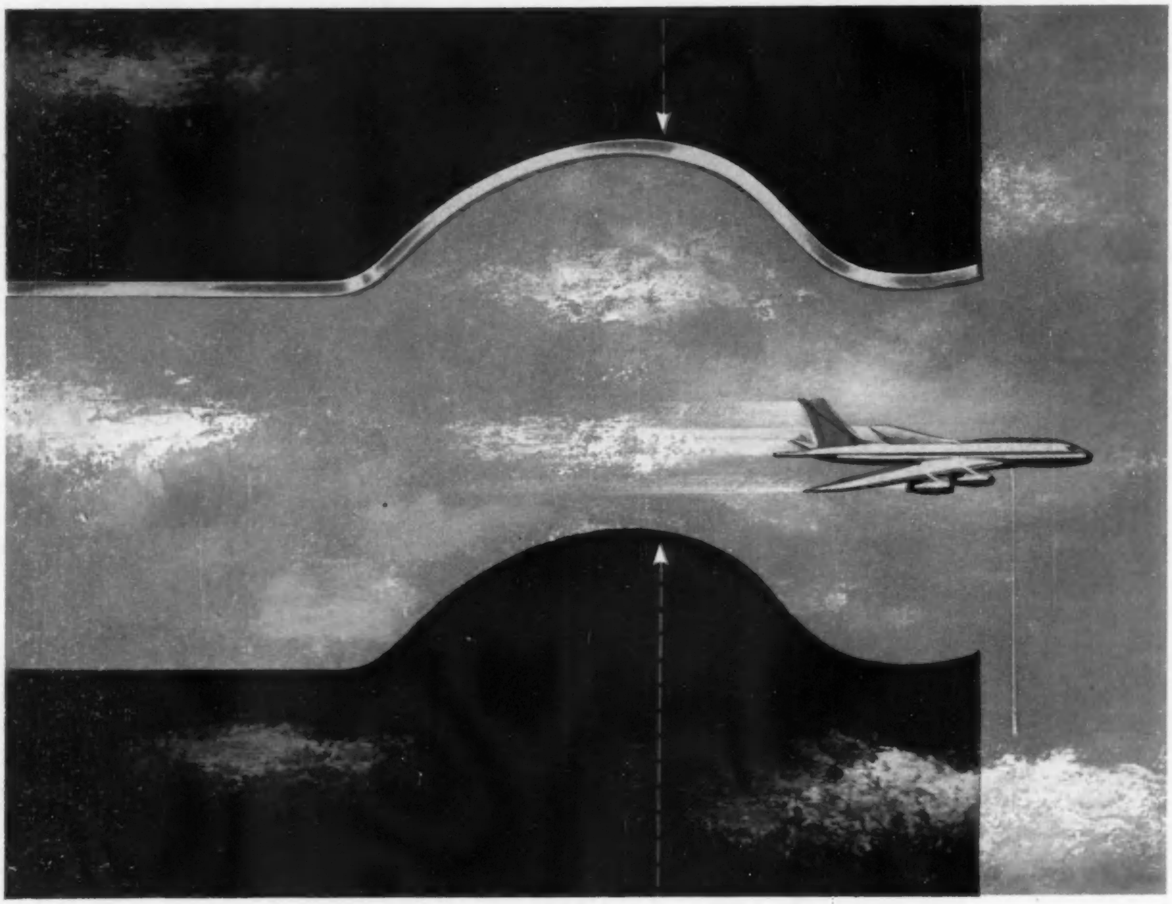
Testing—we have complete laboratory and engine testing facilities.

For the full story of how we can serve you, write our Tappet Division.

THE CHICAGO SCREW COMPANY

ESTABLISHED 1872 • DIVISION OF STANDARD SCREW COMPANY

2701 WASHINGTON BOULEVARD, BELLWOOD, ILLINOIS



Want to save with plastic tools and dies?

Your EPON® RESIN tooling formulator can help you

Tools and dies made of tough but easy-to-handle Epon resin can save you up to two thirds in time, one third in cost! Your tooling resin formulator will show you how Epon resin formulations are saving time and money—*right now*—in applications such as:

High-temperature tooling: Metal-forming stretch dies that can operate at temperatures over 400° F.

Heated tools: Matched dies, with integral heating units, may be made with Epon resin formulations for rapid heat-curing of laminated plastic parts.

Long-lasting metal-forming tools: Castings made of formulated Epon resin, mounted in a crank press, showed no permanent deformation after 28,000 compression-shock cycles.

For tool and die applications, Epon resin formulations offer you the following important advantages:

Excellent tolerance control: Little machining and handwork are required to finish Epon resin tools because of the material's excellent dimensional stability and lack of shrinkage.

Outstanding strength: Jigs and fixtures with thin cross sections can be built from Epon resin-based formulations reinforced with glass cloth. The resulting laminate has high flexural strength and excellent dimensional stability.

Easy modification: Tools and fixtures made from Epon resins may be quickly and easily modified to incorporate design changes.

CONTACT YOUR TOOLING RESIN FORMULATOR

The combination of resin formulator's skill and application knowledge, backed by Shell Chemical's research and resin experience, has solved many important tooling problems for industry. For a list of experienced tooling resin formulators and additional technical information, write to:

SHELL CHEMICAL COMPANY
PLASTICS AND RESINS DIVISION
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6054 West Touhy Avenue	1578 Union Commerce Bldg.	42-76 Main Street	10642 Downey Avenue
Chicago 48, Illinois	Cleveland 14, Ohio	Flushing 55, New York	Downey, California

IN CANADA: Chemical Division, Shell Oil Company of Canada, Limited, Toronto

SHELL

+ INDEX TO ADVERTISERS +


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For the world's finest reliability
Teeth-jarring circuit vibration a problem? How about searing temperatures, 1000F° plus? Maybe metal-eating salt spray or corona is your circuit nemesis.
No matter what the problem is or where . . . by specifying AMP, you can pick the exact solderless terminal for your requirements from the broadest line on the market—whether you require the great production speed of an AMP Automachine or the small run productivity of an AMP precision hand tool.
In fact when you specify AMP, you pick the surest route of all to consistent, economical circuit reliability. If you want a better way to design and manufacture your circuits, send for the full story on AMP's solderless termination program.
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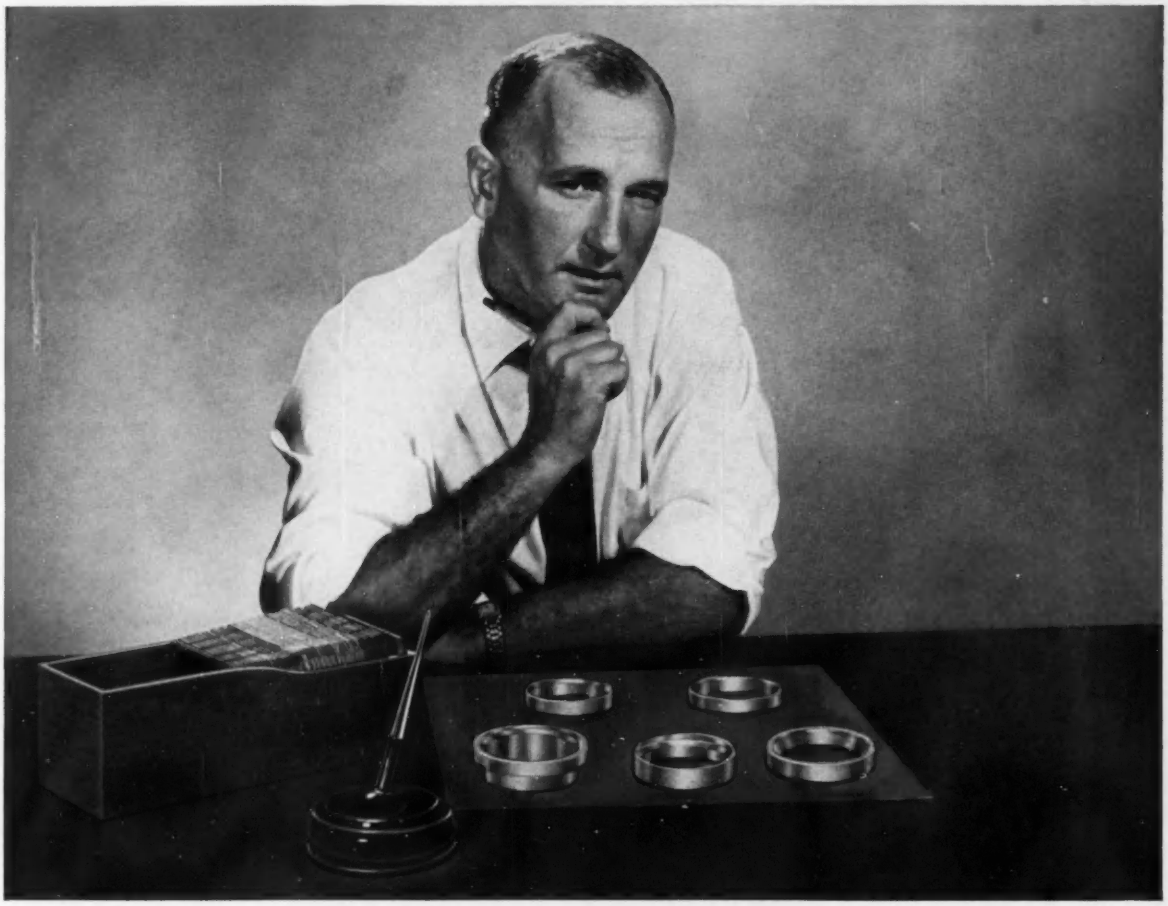
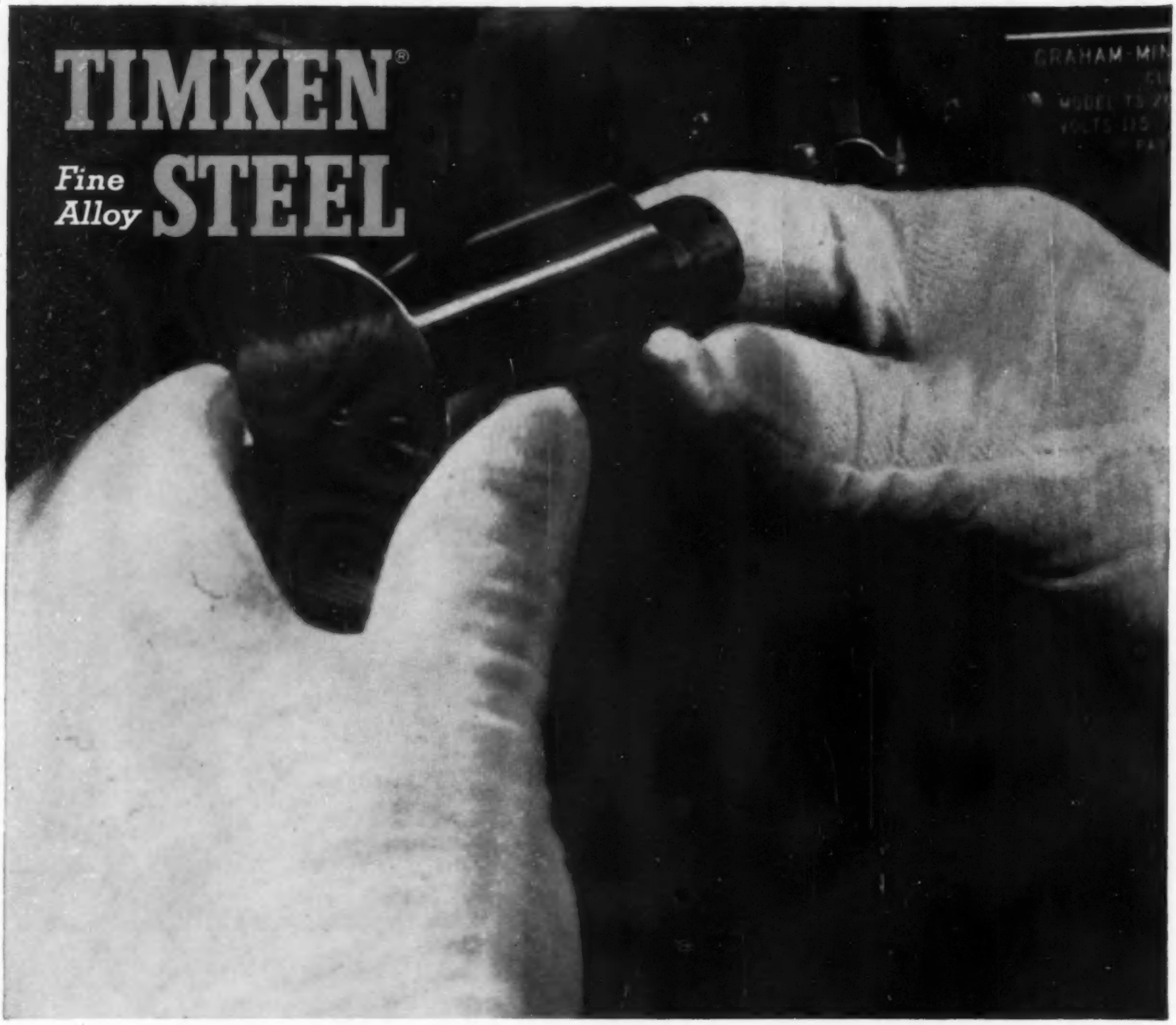
GENERAL OFFICES: HARRISBURG, PENNSYLVANIA
AMP products and engineering assistance are available through subsidiary companies in: Australia • Canada • England • France • Holland • Italy • Japan • West Germany





Why GRAPH-MO® steel makes better gages and dies, cuts cost, too

The master plug gage in the illustration above showed less than 10 millionths of an inch change after twelve years of use. It's made of Graph-Mo®, one of the family of Timken tool steels—the most stable steels you can buy.

In addition to its great stability, Graph-Mo wears longer. As a matter of fact, users report it outwears other ordinary steels 3 to 1. This is because of the combination of free graphite particles and diamond hard carbides in its structure.

And you save money with Graph-Mo. A special oil-hardening tool steel, it machines faster and easier than ordinary steels. As a result, machining time and production costs are reduced.

When you buy Timken steel you get... *1) Quality that's uniform from heat to heat, bar to bar, order to order. 2) Service from the experts in specialty steels. 3) Over 40 years experience in solving tough steel problems.*

All these advantages are yours at no extra cost. Graph-Mo costs no more than other oil hardening tool steels. And remember, there is only one Graph-Mo. The Timken Company makes it.

The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO". *Makers of Tapered Roller Bearings, Fine Alloy Steel and Removable Rock Bits.*

See us at the Atomic Exposition, New York Coliseum, April 4-7, Booth 228

TIMKEN GRAPHITIC STEELS ARE CARRIED IN STOCK BY 9 DISTRIBUTORS WITH 47 WAREHOUSES IN 39 CITIES IN THE UNITED STATES AND CANADA